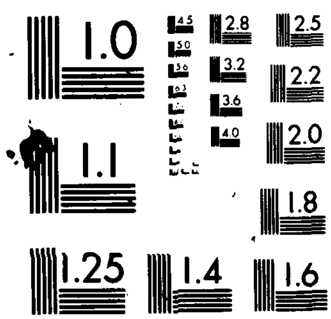
AD-A116 304 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 21/5
CHARACTERISTICS OF A FOUR-NOZZLE, SLOTTED SHORT MIXING STACK WI--ETC(U)
MAR 82 C J DRUCKER

UNCLASSIFIED NL

1 of 3




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

2

# NAVAL POSTGRADUATE SCHOOL

## Monterey, California





# THESIS

**CHARACTERISTICS OF A FOUR-NOZZLE, SLOTTED SHORT MIXING STACK WITH SHROUD, GAS EDUCTOR SYSTEM**

by

Carl John Drucker

March 1982

Thesis Advisor: P. F. Pucci

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

| | |
|---|---|
| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. AD-A116 304 |
| 3. RECIPIENT'S CATALOG NUMBER | |
| 4. TITLE (and Subtitle) Characteristics of a Four-nozzle, Slotted Short Mixing Stack with Shroud, Gas Eductor System | 5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1982 |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) Carl John Drucker | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940 | 12. REPORT DATE March 1982 |
| | 13. NUMBER OF PAGES 279 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | 15. SECURITY CLASS. (of this report) Unclassified |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Mixing Stack
Shroud
Diffuser Rings
Tilted Nozzles
Pumping Coefficient

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Cold flow tests were conducted on a four nozzle (nozzles tilted at a 15 degree angle) gas eductor system to evaluate the system's performance, utilizing a short slotted mixing stack and two shrouds with diffuser rings. The stack length-to-diameter ratio, (L/D), was 1.0, and with the shroud and diffuser rings extended the L/D to 1.5. The difference in the two shrouds was the separation distance

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

between stack and shroud and between shroud and diffuser rings. This separation distance resulted in exit diffuser angles of 10.8 and 7.3 degrees. The nozzles were constructed with a ratio of total area of primary flow to area of mixing stack of 2.5. Secondary and tertiary pumping coefficients, mixing stack pressure distributions, and exit velocity profiles were used to evaluate the shrouded mixing stacks. The stack and shrouds were evaluated with the stack slots closed and then with the slots open. Secondary pumping was found to be independent of changes in diffuser angle. Tertiary pumping decreased with the separation distance and only showed a slight increase when the slots were opened. The 7.3 degree shroud had a lower tertiary flow; however, in the regions of low flow at the exit plane, the severity of the velocity fluctuations was much reduced and hence better overall performance was achieved.

Approved for public release; distribution unlimited.

# Characteristics of a Four-nozzle, Slotted Short Mixing Stack with Shroud, Gas Eductor System

by

Carl John Drucker
Lieutenant, United States Navy
B.S.M.E., Penn State University, 1976

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
March 1982

Author: Carl J. Drucker

Approved by: Paul F. Pucci, Thesis Advisor

Second Reader

P. J. Marto, Chairman, Department of Mechanical Engineering

William M. Tolles, Dean of Science and Engineering

## ABSTRACT

Cold flow tests were conducted on a four nozzle (nozzles tilted at a 15 degree angle) gas eductor system to evaluate the system's performance utilizing a short slotted mixing stack and two shrouds with diffuser rings. The stack length-to-diameter ratio, (L/D), was 1.0, and with the shroud and diffuser rings extended the L/D to 1.5. The difference in the two shrouds was the separation distance between stack and shroud and between shroud and diffuser rings. This separation distance resulted in exit diffuser angles of 10.8 and 7.3 degrees. The nozzles were constructed with a ratio of total area of primary flow to area of mixing stack of 2.5. Secondary and tertiary pumping coefficients, mixing stack pressure distributions, and exit velocity profiles were used to evaluate the shrouded mixing stacks. The stack and shrouds were evaluated with the stack slots closed and then with the slots open. Secondary pumping was found to be independent of changes in diffuser angle. Tertiary pumping decreased with the separation distance and only showed a slight increase when the slots were opened. The 7.3 degree shroud had a lower tertiary flow; however, in the regions of low flow at the exit plane, the severity of the velocity fluctuations was much reduced and hence better overall performance was achieved.

TABLE OF CONTENTS

## LIST OF FIGURES

NOTE: The following figures are a series of performance plots. The figure numbers for each individual plot will not be listed, but can be found in the same sequence order following the first plot.

Comparison Plots

## LIST OF TABLES

NOTE: Due to the number of tables involved, individual table numbers and titles will not be given in this listing. Each table listed below represents a series of tables relating to the particular topic given.

NOTE: Unless otherwise specified, the performance data is for an L/D=1.50, S/D=0.5 with 15/20 nozzles.

<u>Circumferential Velocity Data: 7.3 Degree Effective Diffuser Angle</u>

## NONMENCLATURE

English Letter Symbols

| | |
|---|---|
| A | Area (in.$^2$) |
| c | Sonic velocity (ft/sec) |
| C | Coefficient of discharge |
| D | Diameter (in.) |
| $F_a$ | Thermal expansion factor |
| $F_{fr}$ | Wall skin-friction force (lbf) |
| $g_c$ | Proportionality factor in Newton's Second Law ($g_c$ = 32.174 lbm-ft/lbf-sec$^2$) |
| h | Enthalpy (Btu/lbm) |
| k | Ratio of specific heats |
| L | Length (in.) |
| P | Pressure (in. $H_2O$) |
| $P_a$ | Atmospheric pressure (in. Hg) |
| $P_v$ | Velocity head (in. $H_2O$) |
| PMS | Static pressure along the length of the mixing stack (in. $H_2O$) |
| R | Gas constant for air (R = 53.34 ft-lbf/lbm-R) |
| s | Entropy (Btu/lbm-R) |
| S | Distance from primary nozzle exit plane to mixing stack entrance plane (in.) |
| T | Absolute temperature (R) |

| | |
|---|---|
| u | Internal energy (Btu/lbm) |
| U | Velocity (ft/sec) |
| v | Specific volume ($ft^3$/lbm) |
| W | Mass flow rate (lbm/sec) |
| Y | Expansion factor |

Dimensionless Groupings

| | |
|---|---|
| A* | Ratio of secondary flow area to primary flow area |
| AR | Area ratio |
| f | Friction factor |
| K | Flow coefficient |
| $K_e$ | Kinetic energy correction factor |
| $K_m$ | Momentum correction factor at the mixing stack exit |
| $K_p$ | Momentum correction factor at the primary nozzle exit |
| L/D | Ratio of mixing stack length to mixing stack diameter |
| M | Mach number |
| P* | Pressure coefficient |
| PMS* | Mixing stack pressure coefficient |
| Re | Reynolds number |
| S/D | Standoff; ratio of distance from primary nozzle exit plane to entrance plane of the mixing stack (S) to the diameter of the mixing stack (D) |
| T* | Absolute temperature ratio of the secondary flow to primary flow |

| | |
|---|---|
| $T_t^*$ , TT* | Absolute temperature ratio of the tertiary flow to primary flow |
| $W_s^*$ , W* | Secondary mass flow rate to primary mass flow rate ratio |
| $W_t^*$ , WT* | Tertiary mass flow to primary mass flow rate ratio |
| $\rho^*$ | Induced flow density to primary flow density ratio |

Greek Letter Symbols

| | |
|---|---|
| $\mu$ | Absolute viscosity (lbf-sec/ft$^2$) |
| $\rho$ | Density (lbm/ft$^3$) |
| $\theta$ | Primary nozzle tilt angle |
| $\phi$ | Primary nozzle rotation angle |
| $\psi$ | Nozzle base plate rotation angle |
| $\beta$ | Ratio of ASME long radius metering nozzle throat diameter to inlet diameter |

Subscripts

| | |
|---|---|
| 0 | Section within secondary air plenum |
| 1 | Section at primary nozzle exit |
| 2 | Section at mixing stack exit |
| f | Film or wall cooling |
| m | Mixed flow or mixing stack |
| or | Orifice |
| p | Primary |
| s | Secondary |

t Tertiary (Cooling)

u Uptake

w Mixing stack inside wall

Computer Tabulated Data

| | |
|---|---|
| DPOR | Pressure differential across the orifice (in. $H_2O$) |
| POR | Static pressure at the orifice (in. $H_2O$) |
| PSEC | Static pressure at the mixing stack entrance (in. $H_2O$) |
| PTER | Static pressure in the tertiary air plenum (in. $H_2O$) |
| PUPT | Static pressure in the uptake (in. $H_2O$) |
| TAMB | Ambient air temperature ($^oF$) |
| TOR | Air temperature at the orifice ($^oF$) |
| TUPT | Temperature of air in the uptake ($^oF$) |
| UM | Average velocity in the mixing stack (ft/sec) |
| UP | Primary flow velocity at primary nozzle |
| UUPT | Primary flow velocity in uptake (ft/sec) |
| UPT MACH | Uptake Mach number |
| UE | Average velocity at the mixing stack exit (ft/sec) |
| WM | Mass flow rate from mixing stack (lbm/sec) |
| WP | Mass flow from primary nozzles (lbm/sec) |
| WS | Secondary mass flow rate (lbm/sec) |
| WT | Tertiary mass flow rate (lbm/sec) |

ACKNOWLEDGEMENT

The author wishes to thank all those who aided in the timely completion of this thesis. A special thank you is expressed to LCDR Charles Davis whose thorough turnover and documentation of data reduction programs gave the author a definite advantage in beginning this work.

To Professor Paul F. Pucci, I owe my deepest and sincerest appreciation for the guidance and education given to me during this work. Also, to the personnel of the Mechanical Engineering Machine Shop, thank you for your timely support.

In memory of my father, Peter Drucker, whose inspiration and overwhelming confidence in my ability has helped me complete my research. To him I would like to dedicate this thesis.

# I. INTRODUCTION

As the gas turbine engine becomes more and more a part of today's Navy inventory, special consideration must be given to their particular air breathing and exhausting characteristics. Gas turbines require air-fuel ratios of four to five times that of conventional steam plants of comparable size and as a result large quantities of hot exhaust gas is generated. Along with the increase volume of exhaust gas come increased temperatures, often twice as high as conventional plants. The hot rising exhaust plume contributes to thermal damage to electronic equipment located on the ship's mast; hot gas corrosion of the mast and other superstructures located in the gas wake create other problems. External to the ship, the hot gases represent problems to incoming helicopters and also become an infrared signature from both the gas and the hot external surfaces of the stack.

Operating conditions of the gas turbine determine the volume and temperature of the exhaust gases, therefore some method needs to be employed to counter the problems associated with the exhaust. Initial designs of waste heat boilers to reduce exhaust gas temperatures faultered due to leakage problems, but the idea remains as an economic thermal recovery system. Another energy recovery system

under testing, RACER (RAnkine Cycle Energy Recovery), represents a promising future to utilize the exhaust gas to an effective means.

A simple, effective system to reduce the exhaust gas temperature is the gas eductor. This system has no moving parts, no external system connections and can produce the desired effects. A properly dimensioned eductor system will induce sufficient secondary flow that will, through turbulent mixing, reduce overall exhaust temperature. Another important feature is the resultant negative pressures along the mixing stack which can be utilized to induce a tertiary cooling flow to provide additional mixing thru stack ports or provide film cooling over the outer stack area or both. When a shroud is used the tertiary air provides film cooling of the shroud and subsequently lower external temperatures.

This thesis is a further extension of research conducted by Ellin [Ref. 1], Moss [Ref. 2], Lemke and Staehli [Ref. 3], Shaw [Ref. 4], Ryan [Ref. 5], and Davis [Ref. 8] on the cold flow eductor model testing facility. The initial construction of the eductor model testing facility consisting of an uptake, centrifugal compressor, primary flow nozzles, mixing stack, and a means to control and measure the primary and secondary air flows was conducted by Ellin [Ref. 1]. Figures 1 and 2 show the general layout and terminology utilized in the model. The primary air flow in the testing facility represents a gas turbine's hot exhaust gas. The

secondary air flow is ambient air induced into the entrance of the mixing stack by the primary air flow; see Figure 4. Ellin showed that the one dimensional analysis provided good correlation of data for Mach numbers from 50 to 145 percent of the design Mach number 0.062.

Moss, after initially verifying the one dimensional analysis, as did Ellin, investigated the effects of standoff distances (that distance between the exit plane of the primary flow nozzles and the entrance plane of the mixing stack). The standoff distance in non-dimensional form is divided by the mixing stack diameter to give the S/D ratio. Moss's research resulted in an S/D ratio of 0.5, which maximized eductor pumping. He also determined that using a conical transition at the mixing stack entrance slightly degraded overall performance.

Lemke and Staehli's research included various mixing stack geometric configurations and different area ratio's of primary nozzles. The area ratio for nozzles is defined as the cross sectional area of the mixing stack divided by the total cross sectional area of the primary nozzles. Their results showed that decreasing this ratio from 3.0 to 2.5 decreased back pressure, but also decreased the eductor pumping coefficient. Mixing stack configurations investigated included a solid exit diffuser, a two ring diffuser, a three ring diffuser, a ported mixing stack, and a shroud for the mixing stack. Their two mixing stack

length to diameter ratios were 2.5 and 3.0. They showed with these various geometries that pumping coefficient can be improved without sacrificing back pressure and that sufficient tertiary air flow can be produced to provide film cooling (shroud and diffuser ring geometry) and added mixing air (ported stack).

Davis investigated the effects of tilting and rotating the primary nozzles on the eductor pumping capacity and stack mixing. He tested a wide range of tilt and rotation combinations with the optimum combination being a 15 degree tilt angle and a 20 degree rotation angle. The nozzle area ratio was maintained at [illegible].5 and the standoff ratio (S/D) at 0.5. Davis also continued to shorten the mixing stack length by testing straight mixing stacks with L/D ratio's of 1.75, 1.5 and 1.25.

The object of this thesis is directed toward further reducing the length of the mixing stack while utilizing the principles tested by Lemke and Staehli of shrouding and using diffuser rings. The shorter mixing stack had an L/D ratio of 1.0, but when combined with the shroud and diffuser rings an L/D ratio of 1.5 resulted. The stack and shroud are dimensionally shown in Figures 5, 10 and 11. The stack was slotted in a repeating pattern unlike the ported stack of Lemke and Staehli. Two shrouds with diffuser rings were tested to compare their effects on pumping coefficient, both

secondary and tertiary. The primary nozzles were maintained at a 15 degree tilt angle and a 20 degree rotation angle, a result from Davis' research. The standoff ratio (S/D) of 0.5 was also maintained.

# II. THEORY AND ANALYSIS

This thesis is a further extension of the work conducted by Ellin, Moss, Lemke and Staehli, Shaw, Ryan, and Davis [Refs. 1,2,3,4,5,8] and uses the same one-dimensional analysis of a simple eductor system. Similarity between the basic geometries tested by previous researchers was maintained to correlate data and preserve the error analysis conducted by Ellin. The dimensionless parameters controlling the flow phenomena used previously were also used in the present research along with the basic means of data analysis and presentation. Dynamic similarity was maintained by using Mach number similarity to establish the gas eductor model's primary flow rate.

Although the analysis presented here is for an eductor model with only primary and secondary air flows, the basic discussion applies as well to systems with primary, secondary, and tertiary flows. Systems with tertiary and film or wall cooling air flows have been non-dimensionalized with the same base parameters as the secondary air flow and have been calculated using the same non-dimensional analysis. This allows easier comparison or tabulated and graphic results. Parameters pertaining to the secondary systems are subscripted with an "s" and those relating to the tertiary box are subscripted with a "t".

## A. MODELING TECHNIQUE

Dynamic similarity between the models tested and an actual prototype was maintained by using the same primary air flow Mach number. For the primary air flow Mach number used (0.062), and based on the average flow properties within the mixing stack and the hydraulic diameter of the mixing stack, the air flow through the eductor system is turbulent ($Re > 10^5$). As a consequence of this, momentum exchange is predominant over shear interaction, and the kinetic and internal energy terms are more influential on the flow than are viscous forces. It can also be shown that the Mach number represents the ratio of kinetic energy of a flow to its internal energy and is, therefore, a more significant parameter than the Reynolds number in describing the primary flow through the uptakes.

## B. ONE-DIMENSIONAL ANALYSIS OF A SIMPLE EDUCTOR

The theoretical analysis of an eductor may be approached in two ways. One method attempts to analyze the details of the mixing process of the primary and secondary air streams as it takes place inside the mixing stack. This requires an interpretation of the mixing phenomenon which, when applied to a multiple nozzle system, becomes extremely complex. The other method, which was chosen here, analyzes the overall performance of the eductor system and is not concerned with the actual mixing process. To avoid repetition with previous reports, only the main parameters and assumptions

will be represented here. A complete derivation of analysis used can be found in References [1] and [10]. The one-dimensional flow analysis of the simple eductor system described depends on the simultaneous solution of the continuity, momentum and energy equations coupled with the equation of state, all compatible with specific boundary conditions.

The idealizations made for simplifying the analysis are as follows:

1. The flow is steady state and incompressible.
2. Adiabatic flow exists throughout the eductor with isentropic flow of the secondary stream from the plenum (at section 0) to the throat or entrance of the mixing stack (at section 1) and irreversible adiabatic mixing of the primary and secondary streams occurs in the mixing stack (between sections 1 and 2).
3. The static pressure across the flow at the entrance and exit planes of the mixing-tube (at sections 1 and 2) is uniform.
4. At the mixing-stack entrance (section 1) the primary flow velocity $U_p$ and temperature $T_p$ are uniform across the primary stream, and the secondary flow velocity $U_s$ and temperature $T_s$ are uniform across the secondary stream, but $U_p$ does not equal $U_s$, and $T_p$ does not equal $T_s$.

5. Incomplete mixing of the primary and secondary streams in the mixing stack is accounted for by the use of a non-dimensional momentum correction factor $K_m$ which relates the actual momentum rate to the pseudo-rate based on the bulk-average velocity and density and by the use of a non-dimensional kinetic energy correction factor $K_e$ which relates the actual kinetic energy rate to the pseudo-rate based on the bulk-average velocity and density.
6. Both gas flows behave as perfect gases.
7. Flow potential energy position changes are negligible.
8. Pressure changes $P_{s0}$ to $P_{s1}$ and $P_1$ to $P_a$ are small relative to the static pressure so that the gas density is essentially dependent upon temperature (and atmospheric pressure).
9. Wall friction in the mixing stack is accounted for with the conventional pipe friction factor term based on the bulk-average flow velocity $U_m$ and the mixing stack wall area $A_w$.

The following parameters, defined here for clarity, will be used in the following development.

$\frac{A_p}{A_m}$ area ratio of primary flow area to mixing stack cross section area

$\frac{A_w}{A_m}$ area ratio of wall friction area to mixing stack cross sectional area

$k_p$ momentum correction factor for primary mixing

$k_m$ momentum correction factor for mixed flow

f wall friction fractor

Based on the continuity equation, the conservation of mass principle for steady flow yields

$$W_m = W_p + W_s + W_t \tag{1}$$

where

$$\begin{aligned} W_p &= \rho_p U_p A_p \\ W_s &= \rho_s U_s A_s \\ W_t &= \rho_t U_t A_t \\ W_m &= \rho_m U_m A_m \end{aligned} \tag{1a}$$

All of the above velocity and density terms, with the exception of $\rho_m$ and $U_m$, are defined without ambiguity by the virtue of idealizations (3) and (4) above. Combining equations (1) and (1a) above, the bulk average velocity at the exit plane of the mixing stack becomes

$$U_m = \frac{W_s + W_t + W_p}{\rho_m A_m} \tag{1b}$$

where $A_m$ is fixed by the geometric configuration and

$$\rho_m = \frac{P_a}{RT_m} \quad (2)$$

where $T_m$ is calculated as the bulk average temperature from the energy equation (9) below. The momentum equation stems from Newton's second and third laws of motion and is the conventional force and momentum-rate balance in fluid mechanics.

$$K_p\left(\frac{W_pU_p}{g_c}\right) + \left(\frac{W_sU_s}{g_c}\right) + \left(\frac{W_tU_t}{g_c}\right) + P_1A_1 = K_m\left(\frac{W_mU_m}{g_c}\right) + P_2A_2 + F_{fr} \quad (3)$$

Note the introduction of idealizations (3) and (5). To account for a possible non-uniform velocity profiles across the primary nozzle exit, the momentum correction factor $K_p$ is introduced here. It is defined in a manner similar to that of $K_m$ and by idealization (4), supported by work conducted by Moss, it is set equal to unity. $K_p$ is carried through this analysis only to illustrate its effect on the final result. The momentum correction factor for the mixing stack exit is defined by the relation

$$K_m = \frac{1}{W_mU_m}\int_0^{A_m} U_m^{\,2}\ \rho_2 dA \quad (4)$$

where $U_m$ is evaluated as the bulk-average velocity from equation (1b). The wall skin friction force $F_{fr}$ can be related to the flow stream velocity by

$$F_{fr} = f\ A_w\left(\frac{U_m^{\ 2} \rho_m}{2g_c}\right) \tag{5}$$

using idealization (9). As a reasonably good approximation for turbulent flow, the friction factor may be calculated from the Reynolds number

$$f = 0.046\ (Re_m)^{-0.2} \tag{6}$$

Applying the conservation of energy principle to the steady flow system in the mixing stack between the entrance and exit planes,

$$W_p\left(h_p + \frac{U_p^{\ 2}}{2g_c}\right) + W_s\left(h_s + \frac{U_s^{\ 2}}{2g_c}\right) + W_t\left(h_t + \frac{U_t^{\ 2}}{2g_c}\right)$$

$$= W_m\left(h_m + K_e\ \frac{U_m^{\ 2}}{2g_c}\right) \tag{7}$$

neglecting potential energy of position changes (idealization 7). Note the introduction of the kinetic energy correction factor $K_e$, which is defined by the relation

$$K_e = \frac{1}{W_m U_m^2} \int_0^{A_m} U_2{}^3 \rho_2 dA \tag{8}$$

It may be demonstrated that for the purpose of evaluating the mixed mean flow temperature $T_m$, the kinetic energy terms may be neglected to yield

$$h_m = \frac{W_p}{W_m} h_p + \frac{W_s}{W_m} h_s + \frac{W_t}{W_m} h_t \tag{9}$$

where $T_m = \phi(h_m)$ only, with the idealization (6).

The energy equation for the isentropic flow of the secondary air from the plenum to the entrance of the mixing stack may be shown to reduce to

$$\frac{P_o - P_s}{\rho_s} = \frac{U_s{}^2}{2g_s} \tag{10}$$

similarly, the energy equation for the tertiary air flow reduces to

$$\frac{P_o - P_t}{\rho_s} = \frac{U_t^2}{2g_c}$$

The previous equations may be combined to yield the vacuum produced by the eductor action in either the secondary or tertiary air plenums. For the secondary air plenum, the vacuum produced is

$$P_a - P_{os} = \frac{1}{g_c A_m} \left(K_p \frac{W_p^2}{A_p \rho_p} + \frac{W_s^2}{A_s \rho_s}\left(1 - \frac{1}{2}\frac{A_m}{A_s}\right) - \frac{W_m^2}{A_m \rho_m}\left(K_m + \frac{f}{2}\frac{A_w}{A_m}\right)\right) \qquad (11)$$

where it is understood that $A_p$ and $\rho_p$ apply to the primary flow at the entrance to the mixing stack, $A_s$ and $\rho_s$ apply to the secondary flow at this same section, and $A_m$ and $\rho_m$ apply to the mixed flow at the exit of the mixing stack system. $P_a$ is atmospheric pressure, and is equal to the pressure at the exit of the the mixing stack. $A_w$ is the area of the inside wall of the mixing stack.

For the tertiary air plenum, the vacuum produced is

$$P_a - P_{ot} = \frac{1}{g_c A_m} \left(K_p \frac{(W_p + W_s)^2}{(A_p \rho_p + A_s \rho_s)} + \frac{W_t^2}{A_t \rho_t}\left(1 - \frac{1}{2}\frac{A_m}{A_t}\right)\right.$$
$$\left. - \frac{W_m^2}{A_m \rho_m}\left(K_m + \frac{f}{2}\frac{A_w}{A_m}\right)\right) \qquad (11a)$$

where the primary flow now consists of both the primary and secondary air flows.

C. NON-DIMENSIONAL FORM OF THE SIMPLE EDUCTOR EQUATION

In order to provide the criteria of similarity of flows with geometric similarity, the non-dimensional parameters which govern the flow must be determined. The means chosen for determining these parameters was to normalize equations (11) and (11a) with the following dimensionless groupings.

$$p^* = \frac{\dfrac{P_a - P_{os}}{\rho_s}}{\dfrac{U_p^2}{2g_c}}$$

a pressure coefficient which compares the pumped head $P_a - P_{os}$ for the secondary flow to the driving head $\dfrac{U_p^2}{2g_c}$ of the primary flow

$$PT^* = \frac{\dfrac{P_a - P_{ot}}{\rho_t}}{\dfrac{U_p^2}{2g_c}}$$

a pressure coefficient which compares the pumped head $P_a - P_{ot}$ for the tertiary flow to the driving head $\dfrac{U_p^2}{2g_c}$ of the primary flow

$$W^* = \frac{W_s}{W_p}$$

a flow rate ratio, secondary to primary mass flow rate

$$WT^* = \frac{W_t}{W_p}$$

a flow rate ratio, tertiary to primary mass flow rate

$$T^* = \frac{T_s}{T_p}$$

an absolute temperature ratio secondary to primary

$$TT^* = \frac{T_t}{T_p}$$ an absolute temperature ratio, tertiary to primary

$$\rho^*_s = \frac{\rho_s}{\rho_p}$$ a flow density ratio of the secondary to primary flows. (Note that since the fluids are considered perfect gases,

$$\rho^*_s = \frac{T_p}{T_s} = \frac{1}{T^*_s}$$

$$\rho^*_t = \frac{\rho_t}{\rho_p}$$ a flow density ratio of the tertiary or film cooling flow to primary flows. (Note that since the fluids are considered perfect gases,

$$\rho^*_t = \frac{T_p}{T_t} = \frac{1}{T^*_t}$$

$$A^*_s = \frac{A_s}{A_p}$$ an area ratio of secondary flow area to primary flow area

$$A^*_t = \frac{A_t}{A_p}$$ an area ratio of tertiary flow area to primary flow area

With these non-dimensional groupings, equations (11) and (11a) can be rewritten in dimensionless form. Since both equations follow the same format, only the results for the secondary air plenum will be presented here.

$$\frac{P^*}{T^*} = 2\,\frac{A_p}{A_m}\,((K_p - \frac{A_p}{A_m}\,\beta) - W^*(K_p + T^*)\,\frac{A_p}{A_m}\,\beta$$

$$+ W^{*2}T^*(\frac{1}{A^*}(K_p - \frac{A_m}{2A^*A_p}) - \frac{A_p}{A_m}\,\beta)) \qquad (12)$$

where

$$\beta = K_m + \frac{f}{2}\,\frac{A_w}{A_m}\,.$$

This may be rewritten as

$$\frac{P^*}{T^*} = C_1 + C_2W^*(T + 1) + C_3W^{*2}T^* \qquad (13)$$

where

$$C_1 = 2\,\frac{A_p}{A_m}(K_p - \frac{A_p}{A_m}\,\beta),$$

$$C_2 = -(\frac{A_p}{A_n})^2\,\beta, \text{ and}$$

$$C_3 = 2\,\frac{A_p}{A_m}\,(\frac{1}{A^*} - \frac{A_m}{2A^*A_p}\,\beta - \frac{A_p}{A_m}\,\beta).$$

As can be seen from equation (13),

$$P^* = F(W^*, T^*).$$

The additional dimensionless quantities listed below were used to correlate the static pressure distribution down the length of the mixing stack.

$$PMS^* = \frac{\frac{PMS}{\rho_s}}{\frac{U_p^2}{2g_c}}$$

a pressure coefficient which compares the pumping head $\frac{PMS}{\rho_s}$ for the secondary flow to the driving head $\frac{U_p^2}{2g_c}$ of the primary flow,

where PMS = static pressure along the mixing stack length

$\frac{X}{D}$ ratio of the axial distance from the mixing stack entrance to the diameter of the mixing stack.

## D. EXPERIMENTAL CORRELATION

For the geometries and flow rates investigated, it was confirmed by Ellin and Moss [Ref. 1,2] that a satisfactory correlation of the variables P*, T*, and W* takes the form

$$\frac{P^*}{T^*} = \mathfrak{f}(W^* T^{*n}) \tag{1}$$

where the exponent 'n' was determined to be equal to 0.44. The details of the determination of n = 0.44 as the correlating exponent for the geometric parameters of the gas eductor model being tested is given in Reference [1]. To obtain a gas eductor model's pumping characteristic curve, the experimental data is correlated and analyzed by using equation (1),

that is, $P^*/T^*$ is plotted as a function of $W^*T^{*0.44}$. This correlation is used to predict the open-to-the-environment operating point for the gas eductor model. Variations in the model's geometry will change the pumping ability, which can be evaluated by the plot of equation (1). For ease of discussion, $W^*T^{*0.44}$ will be referred to as the pumping coefficient in this report. Similarly, $WT^{**}TT^{*0.44}$ will be referred to as the film cooling or tertiary pumping coefficient.

# III. MODEL GEOMETRIES

The gas eductor system in this report made use of a single primary flow uptake, a cluster of four primary nozzles (tilted at 15 degrees) within a rotatable base plate, a straight un-shrouded stack and subsequently a short slotted stack with two different shrouds.

## A. MIXING STACK CONFIGURATIONS AND SHROUDS

The main body of this research was to study the effects of a short mixing stack with a shroud and diffuser rings. Initial investigations utilized the short mixing stack used by Davis [Ref. 8]. This stack, the last tested by Davis, had an L/D ratio of 1.25 and was chosen to develop baseline data and to test off-design characteristics of the model.

The mixing stack used along with the shroud and diffuser rings was manufactured from nominally 12 inch O.D. and 11.7 inch I.D. PVC agriculture water irrigation pipe. This stack was the shortest of any of the previously tested stacks: it's L/D ratio was 1.0. The stack was slotted with rectangular shaped slots which repeated every forty-five degrees as seen in Figures 6 and 12. Exact stack dimensions are given in Figure 5. Two shrouds were tested to evaluate film cooling much like the type evaluated by Lemke and Staehli [Ref. 3]. Unlike Lemke and Staehli shroud, the

diffuser rings were attached to the shroud and not the stack. The first shroud-diffuser ring combination was manufactured from 1/16 inch aluminum, cut and rolled to the desired diameters. Spacing between the shroud and stack, and between diffuser rings and shroud was selected to be 1/4 inch. The shroud was designed so that when attached to the stack the overall L/D ratio would be 1.5. Combining the 1/4 inch spacing with the extended length gave an effective diffuser angle of 10.8 degrees. A detailed drawing and photographs can be seen in Figures 10 and 12 respectively. The shroud and diffuser rings had a split along one side to allow easy removal of the shroud without removing the pressure tap tubes.

Pressure taps were installed at 0.25 X/D increments (2.93 inch spacing) to provide more data points for evaluating the stack pressure distribution. Previous stacks used small square pads to support the pressure tap fittings, but these pads would interfere with flow under the shroud or in the case of the second shroud they would prevent flow in that region. Small tubing (one-sixteenth of an inch I.D.) was force fitted into the stack presenting very little resistance to the flow under the shroud.

The second shroud design was similar to the first, but the spacing between stack and shroud and between each of the diffuser rings was reduced to 1/8 inch. The details of this shroud are shown in Figure 11. With the reduction of spacing

the effective diffuser angle was reduced to 7.3 degrees. The diffuser angle is measured from the inside diameter edge of the stack to the inside edge of the outer diffuser ring as seen in both shroud drawings.

## B. ANGLED PRIMARY NOZZLE AND BASE PLATE CONFIGURATION AND GEOMETRIES

The angled nozzle concept was tested by Davis [Ref. 8] and from his data the 15 degree tilt angle and the 20 degree rotation angle were chosen as the optimum nozzle configuration for this research. The nozzles have a constant cross section while having the ability to be inclined and rotated about their centerline axis. The nozzle tilt angle, $\theta$, is the cant angle measured from the centerline of the straight nozzle to the centerline of the angle nozzle. Nozzle rotation, $\phi$, is a measure of the angle through which the nozzle is rotated inward toward the mixing stack centerline from a perpendicular to a radial line from the base plate center to the center of the nozzle. Figures 13 and 14 may provide a clearer visualization of the nozzle configuration. The nozzles were manufactured from clear, cast acrylic pipe with nominal 4.0 inch O.D. and 3.625 inch I.D. which was machined to 3.7 inch I.D. for a nozzle area ratio of 2.5 for the four nozzle group. The angled nozzles were dimensioned so that the intersection of their centerline and exit plane corresponded with the length of the straight nozzles to establish a common measurement for the standoff distance. This allowed alignment of

the nozzles and mixing stack and setting the S/D ratio with the straight nozzles and not having to completely realign the system when the angled nozzles are inserted. Similar materials were used in the construction of the nozzles and base plate so that with the use of tight tolerances and friction the nozzles were held in place even when the base plate was rotated. The angled nozzles and base plate are shown in Figures 15 and 16.

The nozzle base plate was constructed from acrylic plexiglass flat stock. Four recess holes were machined to accept the nozzles, and they were in turn machined to a 0.5 inch radius on the underside to present a smooth flow entrance region for the nozzles. The outer edge of the base plate was machined so that the whole base plate fit inside a matching aluminum base ring. The construction was such that the base plate could be rotated within the ring, primary flow pressure kept the two concentric surfaces mated which eliminated seals, and the base plate could not be ejected from the uptake by the considerable dynamic pressures associated with the high velocity primary air flow. Four symetrically located locking cams allowed the base plate and installed nozzles to be locked in place. This was required for alignment procedures and prevent rotation during initial start-up. Once the system was warmed up to operating conditions, the difference between thermal expansion factors for the ring and base plate allowed sufficient expansion to make the use

of the locking cams unnecessary. In fact, rotation of the base plate could be difficult when the system was fully warmed up, and a dry teflon lubricant was used to help overcome this problem.

A third new parameter was needed for the base plate's ability to be rotated. The base plate rotation angle, $\psi$, is hereby defined as the angle of base plate rotation measured from the 90 degree point on the uptake transition piece as depicted in Figure 15. This parameter serves to give a general indication of the flow directions within the mixing stack due to the angled nozzles. The base plate's geometry and dimensions are given in Figure 16, and a photograph can be seen in Figure 14.

## IV. EXPERIMENTAL APPARATUS

Air is supplied to the primary nozzles by means of a centrifugal compressor and associated ducting schematically illustrated in Figure 1. The mixing stack configuration being tested is placed inside an air plenum containing an airtight partition so that two separate air flows, secondary and tertiary, may be measured. The air plenum facilitates the accurate measurement of secondary and tertiary air flows by using ASME long radius flow nozzles.

### A. PRIMARY AIR SYSTEM

The circled numbers found in this section refer to circled locations on Figure 1. The primary air ducting is constructed of 16-gage steel with 0.635 cm (0.25 in) thick steel flanges. The ducting sections were assembled using 0.635 cm (0.25 in) bolts with air drying silicone rubber seals between the flanges of adjacent sections. Entrance to the inlet ducting 1 is from the exterior of the building through a 91.44 cm (3.0 ft) square to a 30.48 cm (1.0 ft) square reducer, each side of which has the curvature of a quarter ellipse. A transition section 2 then changes the 30.48 cm (1.0 ft) square section to a 35.31 cm (13.90 in) diameter circular section 3 . This circular section runs approximately 9.14 m (30 ft) to the centrifugal compressor inlet.

A standard ASME square edged orifice 4 is located 15 diameters downstream of the entrance reducer and 11 diameters upstream of the centrifugal compressor inlet, thus insuring stability of flow at both the orifice and compressor inlet. Piezometer rings 5 are located one diameter upstream and one-half diameter downstream of the orifice. The duct section also contains a thermocouple just downstream of the orifice. Primary flow is measured by means of the standard ASME square edged orifice designed to the specifications given in the ASME power test code [Ref. 9]. The 17.55 cm (6.902 in) diameter orifice used was constructed out of 304 stainless steel 0.635 cm (0.25 in) thick. The inside diameter of the duct at the orifice is 35.31 cm (13.90 in) which yields a beta ( $\beta$ = d/D) of 0.497. The orifice diameter was chosen to give the best performance in regard to pressure drop and pressure loss across the orifice for the primary air flow rate used (1.71 Kg/sec (3.77 lbm/sec)).

The centrifugal compressor 7 used to provide primary air to the system is a Spencer Turbo Compressor, catalogue number 25100-H, rated at 6000 cfm at 2.5 psi back pressure. The compressor is driven by a three phase, 440 volt, 100 horsepower motor.

A manually operated sliding plate variable orifice 6 was designed to constrict the flow symmetrically and facilitate fine control of the primary air flow. During operation, the

butterfly valve 8, located at the compressor's discharge, provided adequate regulation of primary air flow, eliminating the necessity of using the sliding plate valve. The sliding plate valve was positioned in the wide-open position for all data runs.

On the compressor discharge side, immediately downstream of the butterfly valve, is a round to square transition 9 followed by a 90 degree elbow 10 and a straight section duct 11. All ducting to this point is considered part of the fixed primary air supply system. A transition section 12 is fitted to this last square section which reduces the duct cross section to a circular section 29.72 cm (11.17 in) in diameter. This circular ducting tapers down to a diameter of 26.30 cm (11.5 in) to provide the primary air inlet to the eductor system being tested. The transition is located far enough upstream of the model to insure that the flow reaching the model is fully developed.

B. SECONDARY AIR PLENUM

The secondary air plenum, shown in Figures 1, 2, and 3, is constructed of 1.905 cm (0.75 in) plywood and measures 1.22 m by 1.22 m by 1.88 m (4. ft by 4 ft by 6.17 ft). It serves as an enclosure that can contain all or only part of the eductor model and still allow the exit plane of the mixing stack to protrude. The purpose of the secondary air plenum is to serve as a boundary through which secondary air for the

eductor system must flow. Long radius ASME flow nozzles, designed in accordance with ASME power test codes [Ref. 9] and constructed of fiberglass, penetrate the secondary air plenum, thereby providing the sole means for metering the secondary air reaching the eductor as shown in Figures 1 through 4. Appendix D of reference [1] outlines the design and construction of the secondary air flow nozzles. By measuring the temperature of the air entering and the pressure differential across the ASME flow nozzles, the mass flow rate of secondary air can be determined. Flexibility is provided in measurement of the mass flow rate of secondary air by employing flow nozzles with three different throat diameters: 20.32 cm (8 in), 10.16 cm (4. in), and 5.08 cm (2 in). By using a combination of flow nozzles, a wide variety of secondary cross sectional areas can be obtained.

A secondary air flow straightener, shown in Figures 1 and 2, consisting of a double screen is installed 1.22 m (4 ft) from the open end of the secondary air plenum, between the ASME long radius nozzles and the primary air flow nozzles. The purpose of the straightener is to reduce any swirl effect that could result when only a small secondary air flow area exists.

## C. TERTIARY AIR PLENUM

The tertiary air plenum, shown in Figures 1, 2, 8 and 9, is constructed of 1.90 cm (0.75 in) plywood and measure 1.22 m

by 1.22 m by 1.22 m (4 ft by 4 ft by 4 ft). It serves as an enclosure that completely surrounds the mixing stack and allows the exit and entrance regions to protrude. An airtight rubber diaphragm type seal, schematically illustrated in Figure 2, is located at the entrance to the tertiary plenum (seal between secondary and tertiary plenums). At the tertiary exit the seal slides over the outer diffuser ring with less than an 1/8 inch clearance. A bead of silicone rubber is then used to make the final seal. The seal area expands immediately from the outer diffuser ring diameter to a 30. inch diameter so that the seal does not influence the stack's performance. The seals allow measurement of tertiary air flow independent of the secondary flow. Tertiary air flow is measured with the ASME flow nozzles designed in accordance with ASME [Ref. 9] and constructed of fiberglass. These nozzles are located so that they penetrate the airtight tertiary air plenum, thereby providing the sole means for metering the tertiary air reaching the eductor. By measuring the temperature of the air entering and the pressure differential across the ASME flow nozzles, the mass flow rate of the tertiary air can easily be obtained. Flexibility in measuring the tertiary flow is provided by employing different size flow nozzles: two of 20.32 cm (8 in) throat diameter, three of 10.16 cm (4 in) throat diameter, and two of 5.08 cm (2 in) throat diameter. By using various combinations of these flow nozzles, a wide variety of tertiary cross section flow areas can be obtained.

The interior of the tertiary air plenum is pictured in Figures 8 and 9. The stands which holds the mixing stack can be seen mounted inside the plenum.

D. INSTRUMENTATION

Pressure taps for measuring gage pressures are located inside the primary air uptakes just prior to the primary nozzles, inside the secondary air plenum, inside the tertiary air plenum, and at various points on the model. A variety of manometers, pictured in Figure 18, were used to indicate the pressure differentials. A schematic representation of the pressure measuring instrumentation is illustrated in Figures 17 and 19. Monitoring of each of the various pressures was facilitated by the use of a scanivalve and a multiple valve manifold. The scanivalve was used to select the pressure tap to be read, while the multiple valve manifold allowed selection of the optimum manometer for the pressure being recorded. A vent was included in the multiple valve manifold which provided a means of venting the manometers between pressure readings. The valve manifold provided a selection of a 15.24 cm (6.0 in) inclined water manometer, and a 5.08 cm (2.0 in) inclined water manometer. In addition, the following dedicated manometers were used in the system: a 50.80 cm (20 in) single column water manometer connected to the primary air flow just prior to the primary nozzles, a 1.27 m (50 in) U-tube water manometer with each leg connected to the

piezometric ring on either side of the orifice plate in the air inlet duct, and a 2.55 cm (1.0 in) inclined water manometer connected to the upstream piezometric ring.

Primary air temperatures, measured at the orifice outlet and just prior to the primary nozzles, are measured with copper-constantan thermocouples. The thermocouples are in assemblies manufactured by Honeywell under the trade name Megapak. Polyvinyl covered 20 gage copper-constantan extension wire is used to connect the thermocouples to an Omega Digital Thermometer, Model Number 2176A, which provided temperatures in degrees Fahrenheit or Centigrade. A copper-constantan thermocouple was used to measure secondary/tertiary ambient air temperature. A mercury in glass thermometer was used for comparison purposes.

Velocity profiles at the mixing stack exit plane are obtained by using a pitot tube mounted on a slide bar which is scribed in one-tenth intervals for accuracy and ease of measurement. The slide bar could be mounted to read along the horizontal or diagonal (45 degrees from the horizontal in the counterclockwise direction facing upstream). The pitot tube is fastened to the slide bar with two clamp blocks and can be adjusted to bring the pitot opening flush with the end of the stack. In conjunction with the pitot tube, a 50.80 cm (20 in) single column water manometer or a 6.0 inch inclined water manometer were used to measure the exit pressures.

Threaded studs were used to aide in positioning the traverse (slide) bar in the desired position. The traverse bar and pitot tube assembly was secured to a wood stand with the use of four nuts. The test stand clamps tightly to the exit end of the tertiary plenum. This assembly can be seen in Figure 8.

## E. ALIGNMENT

The alignment of the mixing stack with the primary flow nozzles is accomplished by using two round alignment plugs, a nozzle alignment plate, and a 0.75 inch O.D. steel alignment bar. The two circular alignment plugs are inserted into opposite ends of the mixing stack, and the nozzle alignment plate is then carefully inserted over the straight nozzles. The steel alignment bar is then inserted through the centerline holes in the alignment plugs and brought up to the centerline hole in the nozzle alignment plate. The three axis mounting stand, pictured in Figure 8, is adjusted until the alignment bar can be fully inserted into the nozzle alignment plate and recess in the nozzle base plate without difficulty.

# V. EXPERIMENTAL METHOD

Evaluation of the eductor model requires the experimental determination of pressure differentials across the ASME long radius flow nozzles, temperatures of primary and induced air flows, internal mixing stack pressure distributions, and mixing stack exit velocity profiles from pitot tube pressure readings. In addition, base plate rotation angles are used to get a general understanding of the flow patterns within the mixing stack. These experimentally determined quantities are then reduced with the aid of a computer to obtain pumping coefficients, induced air flow rates, pressure distributions and flow distributions in the mixing stack, and mixing stack velocity profiles at the exit plane of the mixing stack. The plots help to determine the model's relative effectiveness and problem areas which may not be apparent when reviewing raw and processed data.

The following sections address the individual performance criteria used to evaluate the eductor. Circled numbers refer to regions located on the representative plots used in the evaluation process.

## A. PUMPING COEFFICIENT

The secondary pumping coefficient and the tertiary pumping coefficient provide a basis for analyzing the eductor's pumping

capability. Changes in stack geometries such as L/D ratio's, slotting, shrouding, diffuser rings, and spacing between stack and shroud and between shroud and diffuser rings will alter the eductor's pumping performance and the pumping coefficient. The pumping coefficients for the model should correspond to the coefficients for the shipboard eductor system. At the operating point, the eductor is exposed to no restrictions in the secondary or tertiary air flows. In the model, this is simulated by completely opening the air plenums to the environment. Unfortunately, at this condition, the secondary and/or tertiary air flow rates cannot be measured. The eductor model's characteristics must then be established by extrapolating the measured pumping coefficients to the desired operating point.

The data for this extrapolation is established by varying the associated induced air flow rate, either secondary or tertiary, from zero to its maximum measurable rate. These rates are determined by sequentially opening the ASME flow nozzles mounted in the appropriate plenum and recording the pressure drop across the nozzles. Values for nozzle cross sectional areas, pressure drops, induced flow air temperatures, and barometric pressures are then used to calculate the dimensionless parameters P*/T*, W*T*0.44, PT*/TT*, and WT*TT*0.44. The dimensionless parameters are then plotted as illustrated in Figure 21. The data point 1 corresponds to closing all ASME flow nozzles. Data points in region 2

corresponds to opening most of the ASME flow nozzles and the final point corresponds to opening all flow nozzles, plenum doors, or other plenum penetrations available. Early data runs attempted to gain more accuracy in this region by taking more data. Unfortunately, the pressure drop across the nozzles is so critical in this region that any error or fluctuations causes considerable data scatter. Such points were deleted from the finished plots contained in this thesis. In theory, there should be no pressure inside the plenum at the operating point except for ambient pressure, if no restrictions to flow existed. In reality there is always some small negative pressure present since the plenum walls are not totally removed. The data points in region 3 provide the most consistent and accurate data. Extrapolation of the pumping characteristics curve to intersect the zero P*/T* or PT*/TT* abscissa locates the appropriate operating point for the eductor model configuration.

B. INDUCED AIR FLOWS

Secondary and tertiary air flows are induced flows. The secondary air flow is the amount of air induced by the primary nozzles which is mixed within the mixing stack with primary air to reduce the exhaust gas temperature. Tertiary or film cooling air flow is the amount of air induced by the low pressure areas along the mixing stack. The induced air flows between stack and shroud and between shroud and diffuser rings to

maintain a cool outer surface area and eventually mixes with stack air to further cool exhaust gas temperature. When stack slots are open some of the film cooling air enters the stack through the slots to mix with exhaust gases earlier in the mixing stack.

## C. PRESSURE DISTRIBUTION IN THE MIXING STACK

The axial pressure distribution in the mixing stack is obtained by taking static pressure readings from pressure taps attached to the stack in two rows. In the cold flow test facility, the mixing stack is located horizontally in the tertiary plenum. The first row is located on the top of the mixing stack, and the second row is offset 45 degrees from the first row as shown in Figures 6 and 7. The pressure taps were located 0.25 mixing stack diameters apart. Actual locations are given in Figure 6. The dimensionless mixing stack pressure term, PMS*, as derived in Section II is calculated from static pressure data. PMS* is plotted versus X/D pressure tap locations to obtain the mixing stack pressure distribution. A sample distribution is shown in Figure 22. Region 1 is located at the entrance of the mixing stack, and it has the highest negative pressure readings. Pressures near region 2 , located toward the end of the mixing stack (X/D=0.75), although they show a lesser potential for inducing tertiary air compared with region 1 , it still represents a significant pumping capability. The mixing

stack ends at X/D=1.00, where the shroud and diffuser rings continue to X/D=1.50, but no pressure taps were located in the shroud or diffuser rings and therefore, no pressure distribution data for this region is available.

## D. MIXING STACK ROTATION ANGLE

The straight nozzles produce a symmetric flow consisting of four peaks and four null pressure areas along the axis of the mixing stack. Pressure taps at position 'A' normally could be used to record the peaks while the position 'B' taps could be used to record the lower pressure regions or nulls. With introduction of the angled nozzles, the flow became swirled. A rotatable base plate was used to scan the entire circumference of the mixing stack at each L/D position and thereby obtain a better record of the varying axial pressure distribution. This allowed the peaks and troughs to be rotated to the stationary pressure taps for data acquisition. The base plate rotation angle, $\psi$, is recorded for each pressure tap position, and when plotted, provides a rough indication of the flow pattern variations.

Tests were conducted early in Davis' research to determine the sensitivity of the rotation angles. Results showed that changes as small as one degree of rotation could cause large pressure changes while at other times the base plate could be rotated 30 degrees without any pressure changes.

E. VELOCITY TRAVERSES

The velocity traverses are generated by traversing the pitot tube in measured increments across the horizontal and diagonal lines as indicated in Figure 7. Stagnation pressure readings are read from the 20 inch vertical manometer or the 6 inch inclined manometer and combined with atmospheric pressure and ambient temperature to calculate mixing stack exit velocities in units of feet per second. Computer generated two-dimensional plots of the velocity traverses can then be used to get indications of mixing, wall effects, and primary flow core information.

The sample horizontal velocity profile shown in Figure 23 shows two, essentially primary flow peaks at regions 2 and 4 . Regions 1 and 5 are essentially secondary induced flows and show some wall effects. Region 3 should be symmetrically located at the center of the stack, however misalignment of the base plate, non-symmetric nozzle placement, and unequal pumping by the four primary nozzles are a few of the things that could cause the center trough to appear displaced. Region 6 should have data points which overlap data points on the diagonal velocity plot.

The sample diagonal velocity profile shown in Figure 24 shows noticeable peaks and troughs. The peaks at regions 1 and 7 are the primary nozzle flows which have not been rotated inward enough to get better mixing. The peaks at 3 and 5 correspond to peaks 2 and 4 on

the horizontal velocity profile. Region 8 data points should be the same as those in the other profile. This region also is observed for coring effects when the nozzles have excessive tilt and rotation.

The dashed lines in both sample profiles are just rough indications of what a fully developed turbulent flow should look like. With the short mixing stacks, this will never be achieved, but the goal is to select nozzle combinations which can give generally flat overall profiles as an indication of enhanced mixing. Sharp peaks and troughs should therefore be avoided or minimized. The comparison plots of the two profiles serve to determine data accuracy, the interaction of the flows, and base plate misalignment which can seriously skew the profiles.

Due to the flow rotation created by the angled primary nozzles, the nozzles base plate had to be rotated on a trial-and-error basis to bring the primary flows into alignment with the pitot tube for the diagonal velocity traverse profile. This setting of the nozzle base plate was kept intact for the horizontal velocity profile. Alignment procedures called for obtaining a peak pressure reading on the diagonal traverse, adjusting the sliding scale on the velocity traverse bar and moving the bar until a symmetric profile was achieved, and then verifying the base plate rotation.

## F. LOW FLOW REGIONS

Some specialized data was taken to investigate regions of low flow and possibly reverse flow in certain regions of the stack. The need for this investigation was first observed during testing of the 10.8 degree diffuser angle shroud. Four dual ended pitot tubes were manufactured and installed in the diffuser rings as shown in Figure 20. The pitot tubes were installed 90 degrees apart, two in the outer diffuser ring and two in the inner ring. The tubes were aligned such that they were in line to the flow direction and midway between the diffuser rings. The tube alignment was important to insure the tubes were not influenced by one wall more then the other and to maintain flow alignment for true stagnation pressure readings.

## VI. DISCUSSION OF EXPERIMENTAL RESULTS

As in past theses on eductor systems the discussion of the investigation will be confined mainly to the amount of induced air flows within the mixing stack, both secondary and tertiary; the amount of film cooling air available to cool the exterior of the eductor system; and mixing stack mixing of primary, secondary and tertiary air. Back pressure on the turbine exhaust caused by the eductor system is primarily fixed by the nozzle area ratio which was tested and confirmed by Davis [Ref. 8] and Lemke and Staehli [Ref. 3]. This is not a major area of discussion here since the nozzle area ratio was maintained at 2.5 and the back pressure remained relatively constant at 6.15 inches of water.

Throughout the entire investigation the standoff ratio (S/D) was maintained at 0.5. The nozzles utilized were the 15 degree tilt angle nozzles tested by Davis. During the discussion these nozzles will be referred to by their degree of tilt and their degree of rotation (i.e. 15/20 nozzles will mean 15 degree tilt and 20 degree rotation). Also when reference is made to the shrouded two ring stack, it should be clear that the two diffuser rings are attached to the shroud as shown in Figures 10, 11, and 12, and that the shroud with the diffuser rings are a separate unit from the stack. Another term which will be used repeatedly will

be the effective diffuser angle or simply diffuser angle which is the angle made by the increasing exit area of the stack, shroud, and diffuser rings with the stack axis as if it were a solid diffuser.

The tabulated data is presented in the same format as Davis. During the discussion of this data the following abbreviations will be used; PCD for pumping coefficient, MSD for mixing stack pressure distribution, and VTD for velocity traverse distribution. Along with the data is a series of mini-plots which can prove to be helpful when reviewing the data.

Initial data was taken utilizing a straight mixing stack, L/D=1.25, and 15/10 nozzles. This data was taken to develop a data baseline and to fulfill one of the recommendations made by Davis. Davis had tested this stack/nozzle combination for pumping coefficient data only. A full data run was made to establish a more complete data base for the 15 degree tilt angle nozzles. This data is presented in Figure 25 and Table 1. Pumping coefficient data plotted directly on top of Davis' with a coefficient of slightly greater than 0.58. When compared to the 15/20 nozzles, the 15/10 showed a slight improvement. Mixing stack comparisons with 15/20 nozzles did not give as good results. Velocity traverse data (VTD) profiles for the 15/10 nozzles had a better horizontal, but a worse diagonal profile when compared to the 15/20's; overall they were the same.

## A. L/D=1.25 (SHORT STACK) OFF DESIGN CHARACTERISTICS

Ellin [Ref. 1] was the first to test of design characteristics of the exhaust gas eductor model by varying uptake Mach number from 0.030 to 0.090. This represents a testable range from 50 percent to 145 percent of the design Mach number of 0.062. Ellin's testing of a four nozzle configuration of his eductor proposals A and B indicated that the uptake Mach number has no effect on pumping coefficient. He also showed an improvement in mixing corresponding to increases in uptake Mach number. For this research uptake Mach numbers were varied from 50 percent to 120 percent of the design Mach number. Three values of Mach number were chosen to be evaluated on the straight mixing stack (L/D=1.25), four angled nozzle (15/20 nozzles) eductor configuration. Once again the dependency of pumping coefficient on Mach number was to be tested for the now short single stack, angled nozzle eductor. Each of the three Mach number's were evaluated with full data runs of PCD, MSD, and VTD data. The processed data can be seen in Tables 2 through 4 and Figures 26 through 28. Comparisons of pumping coefficients for 50, 75, and 120 percent of design Mach number with data taken by Davis shows that pumping coefficient is again independent of Mach number for the present eductor configuration. Mixing stack data had a slight degradation in the 'B' position and little or no change in the 'A' position. This degradation of axial pressure distribution, PMS*, was similar

in all three cases tested and is not a function of Mach number. Similar velocity profiles, VTD, showed no visible trends with varying Mach numbers. The use of shorter stacks and angled nozzles does not effect the off design performance of the eductor system.

B. 10.8 DEGREE DIFFUSER ANGLE SHROUD

The 10.8 degree diffuser angle shroud was the first short stack with shroud and diffuser rings tested since Lemke and Staehli's research on a long stack (L/D=2.5) configuration. The only variation of Lemke and Staehli's research which is similar to the present design was their flow through shroud/ diffuser ring combination. The short stack was installed with the slots closed and the shroud with diffuser rings clamped to the stack. A method had to be devised to close the stack slots and not interfere with mixing within the stack. Thin plastic tape was selected to close off the slots on the outside of the stack. Placing the tape on the outside of the stack eliminated the problem of any interference on mixing, but forced the removal of the stack and shroud to remove the tape. This increased the time to change configurations from slots closed to slots open due to removal, installation and alignment of the stack. Although the shroud and diffuser ring unit was slit along one side for ease of installation over the stack, it was manufactured so that when clamped to the stack the mating edges butted together with no overlap

and the seam was covered by heavy tape placed on the outside of the shroud and diffuser rings to prevent any leakage of tertiary air through the shroud. The slots closed data is shown in Figure 29 and Table 5. The secondary pumping coefficient improved over the straight stack (L/D=1.5) with the same nozzle configuration. A coefficient of 0.62 was achieved with the shroud and diffuser rings versus 0.58 for the straight stack. An added feature of the shrouded stack is the film cooling or tertiary air flow. In this case a tertiary pumping coefficient of 0.12 provided a significant increase over the flow through version of Lemke and Staehli. The mixing stack pressure distribution of the short stack and shroud was similar to the straight stack with the exception of the entrance value of the 'B' position, which showed a significantly higher negative pressure which in conjunction with the diffuser exit explains the higher pumping coefficient. No comparison of velocity distributions were made due to the different base plate rotations used for the shrouded stack and straight stack with the same L/D. A slight misalignment of the mixing stack, or unequal pumping, etc., can be seen in the comparison plot of horizontal and diagonal velocity traverse's by the unsymmetrical plots and the center minimum velocity of the horizontal and diagonal are not in the stack center. Verification of the secondary pumping coefficient was run with the same improved results.

The stack was removed to open the slots; then installed and realigned. Secondary pumping coefficient was not influenced by the change in slot configuration and remained at 0.62. Tertiary pumping was effected by the low mixing stack pressures causing an increased flow under the shroud. Actual measurement of the flow through the slots was not attempted. The tertiary coefficient improved to 0.135 vice 0.12 with the slots closed. A marked decrease in stack wall negative pressures, MSD, was observed as a result of increased tertiary flow into the mixing stack. This data is represented in Figure 30 and Tables 7 and 8. An important observation was made during velocity traverse testing. The diagonal traverse was peaked as usual and the profile was symmetrical with four peaks and three troughs with the peaks being slightly more prominant then with a straight stack. The discrepancy came when recording the horizontal velocity traverse. For the first 1.5 inches of traverse travel the pressure reading was zero indicating no positive flow in that region. The profile was not symmetrical, but the traverse readings again zeroed prior to the end of the traverse travel. This region of low flow had not been predicted and required further investigation. The results of this investigation will be discussed in a later section.

Initially after discovering the low flow region, the nozzle rotation was rotated to 10 degrees to analyze its effect on this region. The pumping coefficients and MSD

data showed no significant change (Table 9 and Figure 31) while the horizontal velocity traverse remained zero for the first 2.5 inches of travel. This confirmed the need for investigation of this phenomenon.

## C. 7.3 DEGREE DIFFUSER ANGLE SHROUD

After analyzing the regions of low flow a new shroud was designed to test the effect of the diffuser angle on these regions and to analyze it's pumping capability. A reduction in the spacing between the stack and shroud and between diffuser rings reduced the effective diffuser angle to 7.3 degrees. Once again, prior to installing the shroud the slots were closed for initial data runs. The reduction in diffuser angle and reduced spacing had no effect on secondary pumping coefficient, while the tertiary flow was drastically reduced. As seen in Figure 32 and Tables 10 and 11 the tertiary pumping coefficient is 0.06. This is half the value of the previous shroud. The only change in MSD data was a decrease in the minimum entrance pressure (position 'B') while all other points showed no relative change. When peaking the diagonal velocity traverse a different base plate rotation was used. The horizontal traverse showed a significant positive flow just off the zero travel position, but this did not mean the low flow regions did not exist and further investigation was deemed necessary. The overall combined velocity profiles for this shroud appear flatter

and more uniform than the previous shroud. A full data verification run (Table 11) was made to validate the initial data.

The shroud was removed for opening of the slots and then reinstalled. Secondary pumping coefficient remain unchanged, while the tertiary flow again increased due to opening the slots. MSD data was reduced for all points on the 'B' position, but no significant trends were seen. The same base plate rotation angle was used as when the slots were closed and similar velocity profiles were produced (Figure 33 and Table 12). Another full verification run was made to test the validity of the results and is presented in Table 13. No significant changes were observed during the run.

D. LOW FLOW INVESTIGATION

After discovering the low flow regions during traverse testing a means to further investigate possible flow instabilities had to be devised. The first check was to ensure that there was flow between the diffuser rings in the positive direction (i.e. from the shroud end to the exhaust exit plane). Four dual pitot tubes were constructed and installed in the 10.8 degree diffuser shroud. Figure 20 shows their position in the diffuser rings. This testing was used to determine the existence of flow reversals which could carry hot exhaust gases over the diffuser rings causing hot spots. The first data was made by rotating the base plate from 0 to 90 degrees in 10 degree increments

and recording the pressure readings from all pitot tubes. The stack slots remained open during this testing. All four sets of pitot tubes indicated positive flow at all positions of base plate rotation. Very little variation at any one position was seen during the base plate rotation which indicates that the flow over the diffuser rings is constant and independent of base plate rotation. The pitot tubes in the inner diffuser ring showed a higher flow rate than the outer ring, which corresponds to its axial position on the shroud being more influenced by the negative pressures within the stack. Another data run was made to verify the first with the addition of horizontal and diagonal traverse's being taken at each base plate position. Only the first and last 2.5 inches of traverse data were taken since this was the area where the flow instabilities were first observed. To decrease the length of time of a data run, base plate rotation angles of 0, 10, 30, 50, 70, and 90 degrees were used. If at the end of any run no instabilities were observed, the other base plate angles would be tested. At 0 and 90 degrees the horizontal traverse's demonstrated severe oscillations in pressure readings with some slight negative pressures being recorded (approximately 0.1 inches of water) near the edges. These instabilities existed over the first and last 1.5 inches of traverse travel. At 10 degrees horizontal traverse oscillations were again observed, but not nearly as severe as those at 0 and 90 degrees. The diagonal traverse

showed rapid increases in exit pressure readings at these positions. At 50 degrees the diagonal traverse showed unstable flow much like the horizontal at 0 degrees. This indicated that these regions of low flow were symmetrically located around the stack, occurring approximately every 90 degrees depending on the base plate rotation. Diffuser ring pitot tubes again confirmed constant positive flow in that region of the diffuser rings. A tuft was placed at the end of a long thin rod and slowly moved across the horizontal; the base plate was positioned at 0 degrees. Violent fluctuations were observed for approximately the first 2 inches inward from the outer edge. At infrequent intervals the tuft would be sucked into the stack and then back out again. This confirmed the oscillations seen in the traverse readings and also the slight negative pressures. Beyond 2 inches the tuft stiffened with very little fluctuation. The tuft was then positioned at a distance approximately half way between the outer and the inner diffuser rings and rotated from the horizontal toward the diagonal through to the top of the stack at all times maintaining the distance from the outer diffuser ring edge. Fluctuations were observed from 0 to 10 degrees, then the tuft stiffened and remained stiff until the top of the stack was reached where the tuft again began to fluctuate. This verified what was seen during the traverse testing. A second run was made under similar conditions and yielded the same results.

When the nozzles were rotated to 10 degrees for a full data run, a set of data as described above was taken in this configuration. The fluctuations on the horizontal traverse at base plate rotations of 0, 10, and 90 degrees were not as severe as those observed with 15/20 nozzle configuration. Oscillatory readings about zero were observed from 0.0 to 1.0 inch of traverse travel. The dual ended pitot tubes showed again constant positive flow at all positions of base plate rotation.

To test the influence of the slots on the flow instability data, the shroud was removed, the slots were closed and the shroud reinstalled. The nozzles were rotated back to the 20 degree position and another set of traverse's and dual ended pitot readings were taken. No significant difference could be seen between the slots open and the slots closed readings. The fluctuations were the same at 0, 10, and 90 degree rotations for the horizontal traverse and the 50 degree rotation for the diagonal traverse.

When the 7.3 degree diffuser angle shroud was installed and tested, no instabilities were observed during the velocity traverse data taking. As stated earlier a different base plate rotation angle was used during these runs and no conclusion could be made regarding the existance of low flow regions. Since the dual ended pitot tubes demonstrated positive flow in all cases of the 10.8 degree shroud, they were not utilized in the 7.3 degree shroud. Also, the

decreased separation between rings would have made them difficult to install. To search for low flow regions horizontal and diagonal traverses were taken while rotating the base plate in 10 degree increments from 0 to 110 degrees. Two runs were made, one with the slots closed and one with the slots open, both used 15/20 nozzles. The first run with slots closed provided some promising data. Instabilities were observed at 10 degrees, but the severity had diminished so that oscillations occurred within the first and last inch of horizontal traverse travel. These same oscillations were not apparent on the diagonal traverse at 50 degrees rotation.

When the slots were opened another round of data was taken at the same points. Again the oscillations occurred at 10 degrees, with the same results as above. The only difference in performance between the two runs was the return of oscillations on the diagonal traverse with the base plate rotated to 50 degrees. The oscillations were minor and only within the first inch of travel.

The data taken on these two runs was reduced and displayed in the same manner as previously used for velocity traverses. The data is displayed as velocity versus circumferential location for a given distance from the edge of the outer diffuser ring. Data from 0.2, 0.5, 0.8 and 1.5 inches from the edge was considered representative of this region of the stack. Since the base plate angle increases counterclockwise from the horizontal towards the top, this angular positioning

was used for the plots. For example, when the base plate was rotated to 10 degrees the horizontal traverse data was plotted as 350 on the near end and 170 degrees for the far end as if the horizontal traverse was being rotated clockwise around the shroud. Figures 38 and 39 and Tables 14 and 15 represent these two runs. All the velocity profiles are sinusoidal with four peaks representative of the four nozzle flows. Moving in towards the center, the peaks increase more rapidly than the troughs and the regions of low flow are apparent in all profiles. These profiles indicate that the four flows remain independent at the outer regions of the stack. The question that remains is; will these flows be sufficient to maintain a cool outer surface of the shroud and diffuser rings?

Finally, short tufts were taped approximately a half an inch apart around the outer edge of the outer diffuser ring and also at the entrance to the stack. The base plate was fixed at the zero degree position. Figures 34 and 35 are photographs of the entrance and exit flows respectively. From the photographs the independent flows can be seen entering and exiting the stack. At the entrance, the tuft that is not moving separates two flows and at the exit the low flow regions are seen by the limp tuft shown by the arrow.

## E. COMPARISON

Comparison plots can be found in Figure 38 (slots closed) and Figure 39 (slots open). First, the two shrouds tested in

this research are compared; then plots of these shrouds in comparison with stacks from other research are shown. Of the two shrouds tested with slots closed the 10.8 degree diffuser angle shroud provided better tertiary pumping. All other parameters can be considered equal. With the slots open similar results can be seen. The 10.8 degree shroud provides a greater tertiary flow for film cooling, but something not seen in these plots is the increased problem of low flow and instabilities that was found during special testing.

When comparing the two shrouded stacks with previous research, these stacks provided a better secondary pumping coefficient than a straight stack (Davis [Ref. 8]) of the same L/D, but not as good as the ported mixing stack with ring diffuser and flow through shroud tested by Lemke and Staehli [Ref. 3]. Tertiary flow for both new shrouds was better than the ported mixing stack. The mixing stack pressure distribution was comparable for all four stacks with no outstanding differences. Both new shrouded stacks with their shorter lengths (lower weight) and good pumping coefficients are good choices as an eductor system. Both require hot exhaust gas testing to investigate the effect of low flow regions on the shroud and diffuser ring external temperatures.

# VII. CONCLUSIONS

This research investigated the effects on the eductor system's overall performance of reducing the mixing stack length, slotting the stack, and shrouding the stack with a shroud-diffuser ring arrangement. The conclusions from this investigation are as follows:

1. The one-dimensional analysis used in this research provides good correlation of data for Mach numbers from 50 to 120 percent of the design Mach number of 0.062.
2. An improvement in secondary pumping was obtained by using a short stack and shroud-diffuser ring arrangement over a straight stack with the same L/D ratio.
3. Secondary pumping is independent of effective diffuser angle.
4. Tertiary pumping was increased by increasing the diffuser angle.
5. Tertiary pumping increased when the stack slots were opened with both shroud designs.
6. The shroud and two diffuser ring configuration provides film cooling where it could be most effective to provide a thermal shield for the mixing stack.
7. Low flow regions were more prevalent in the 10.8 degree diffuser angle than with the 7.3 degree diffuser angle.

## VIII. RECOMMENDATIONS

Based on the findings of this investigation the following recommendations for future research are presented:

1. Test the same two mixing stack, shroud, and diffuser ring arrangements using hot gas for the primary air flow. Special attention must be used in the placement of the thermocouples to investigate the effects of the low flow regions on the outer surface temperature. Also correlate these results with the cold flow data contained herein.
2. With temperature and pressure distribution data obtained from tests conducted using hot gas as the primary air flow, investigate the effects the slots have on mixing and exit temperatures.
3. Investigate alternate nozzle cross sections, such as the fluted nozzle, to further enhance the mixing process in short mixing stacks. These nozzles should be tested with the short shrouded stack tested in this research.

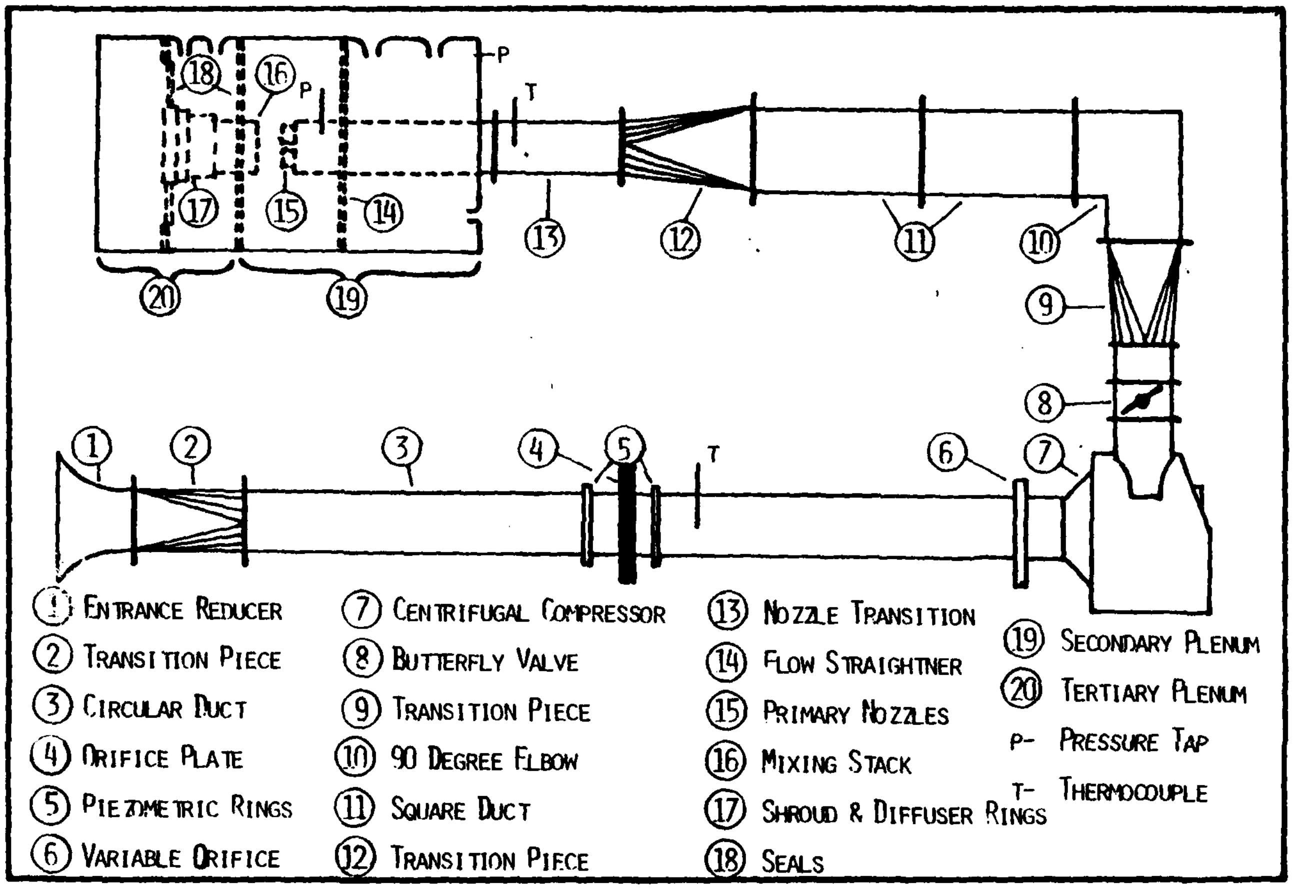



Figure 1. Eductor Model Testing Facility

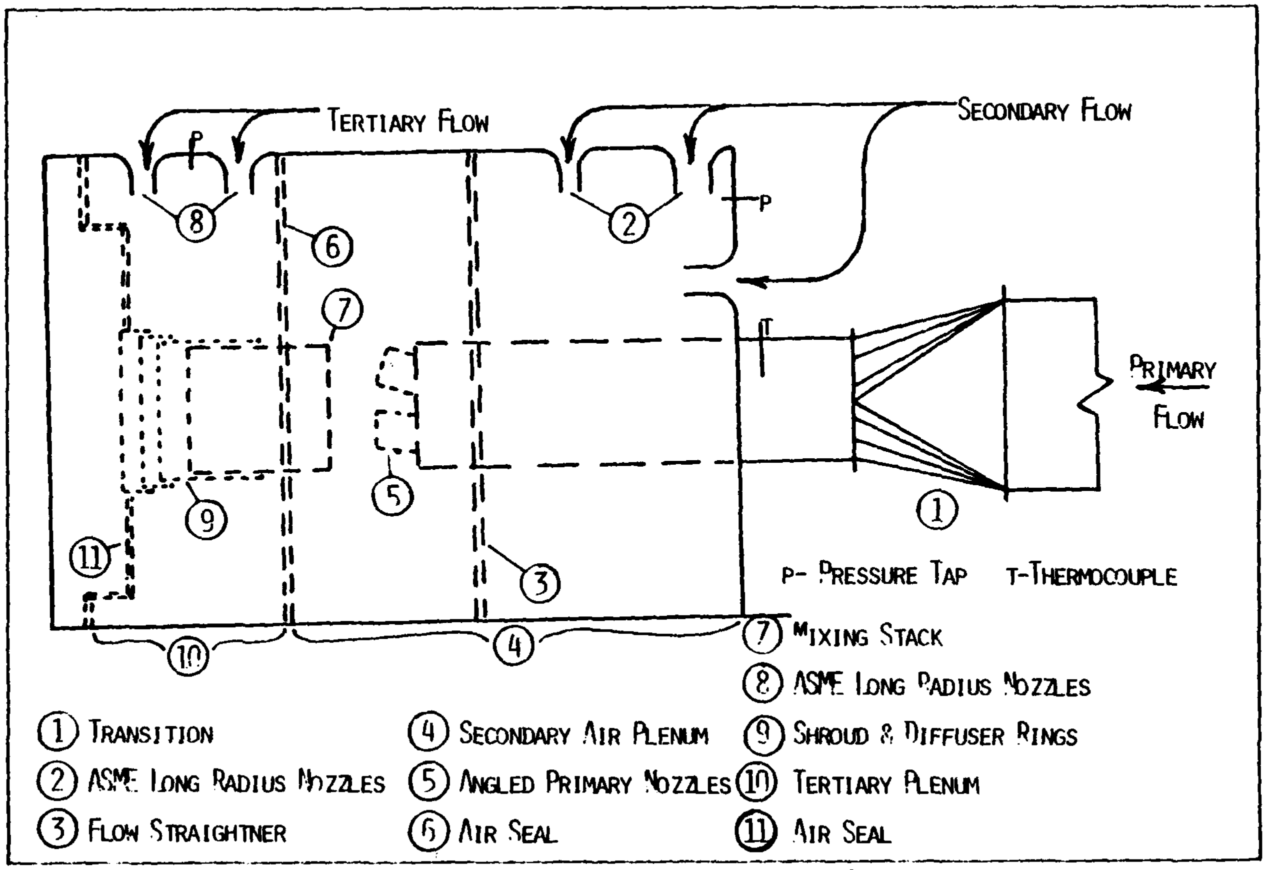



Figure 2. Test Facility with Secondary and Tertiary Plenums

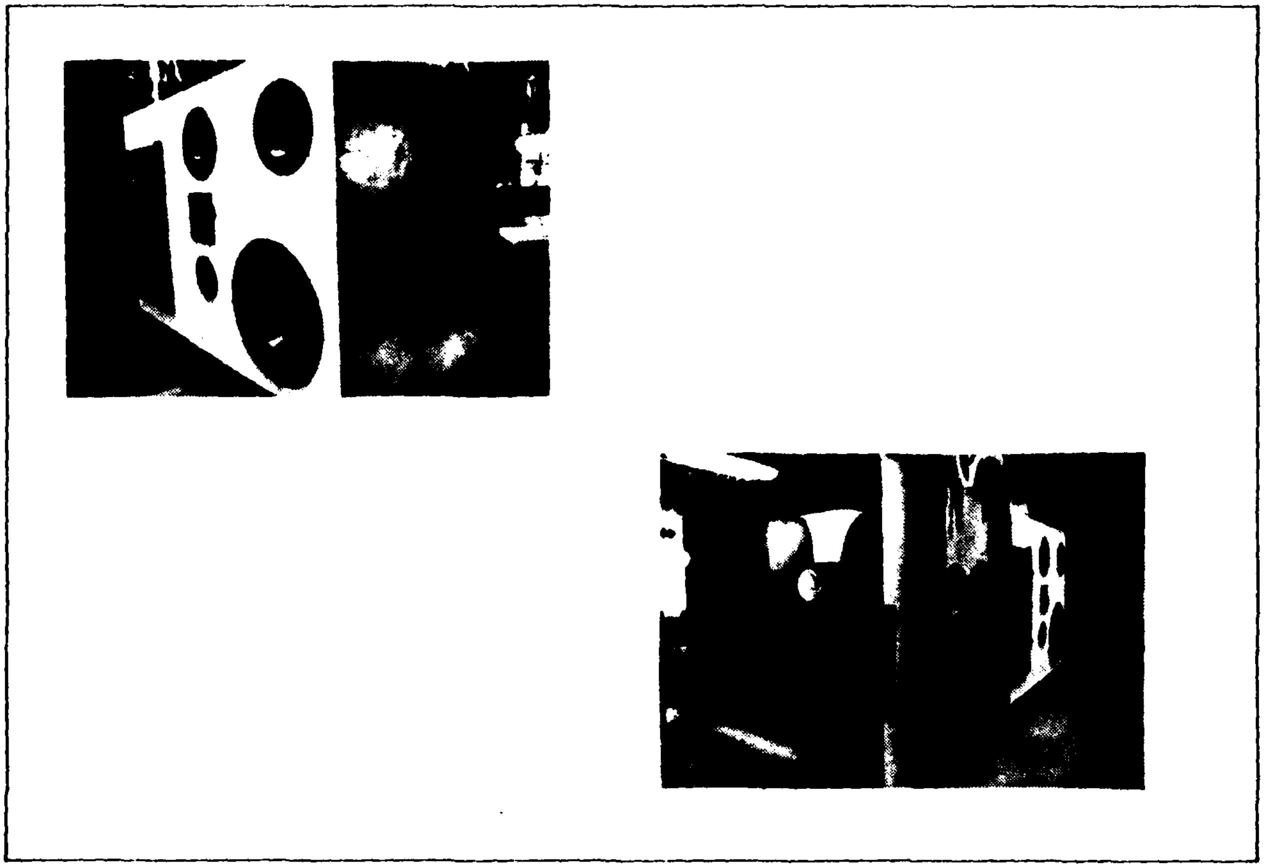


Figure 3. Exterior of Secondary and Tertiary Plenums

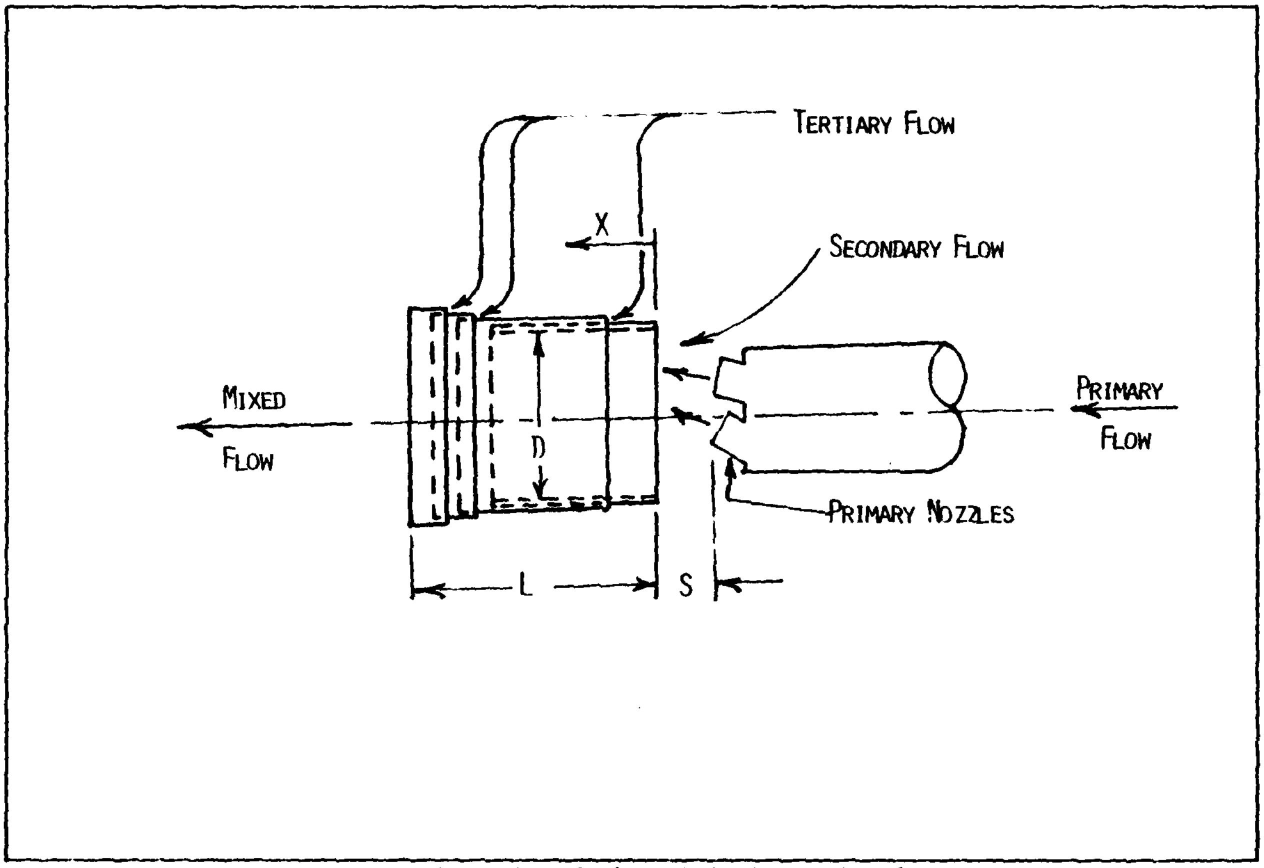



Figure 4. Schematic of Shrouded Mixing Stack Gas Eductor with Angled Nozzles

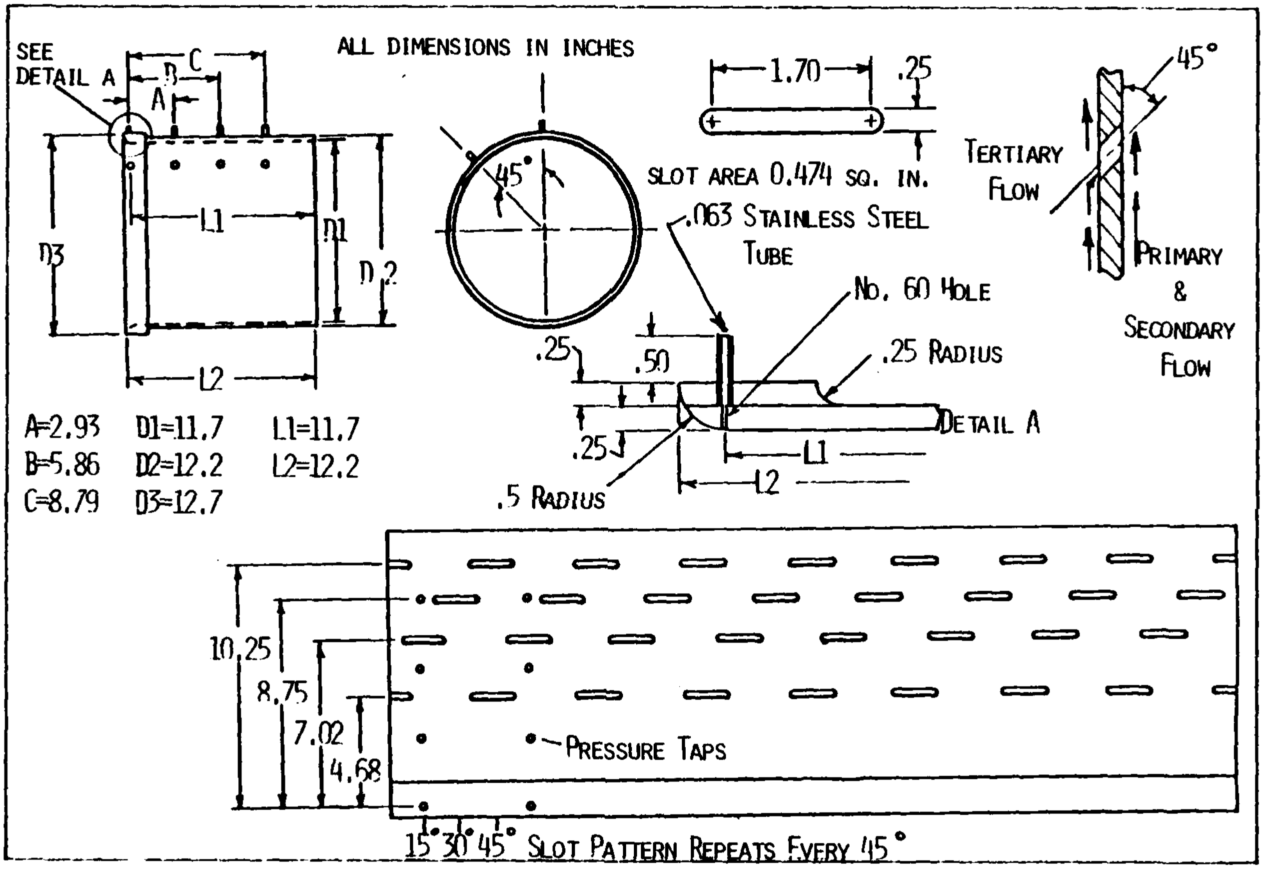



Figure 5. Dimensions of Slotted Mixing Stack

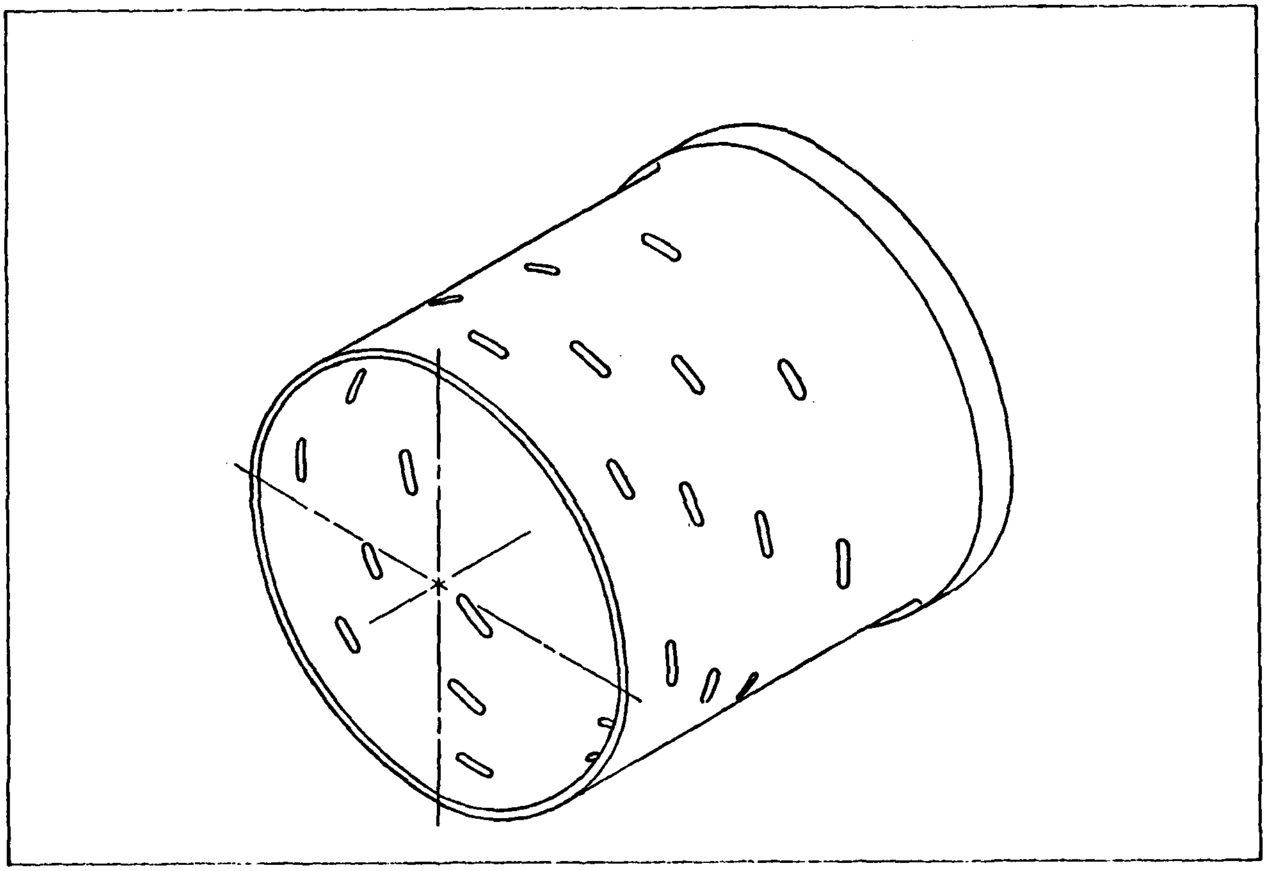


Figure 6. Isometric View of Slotted Mixing Stack

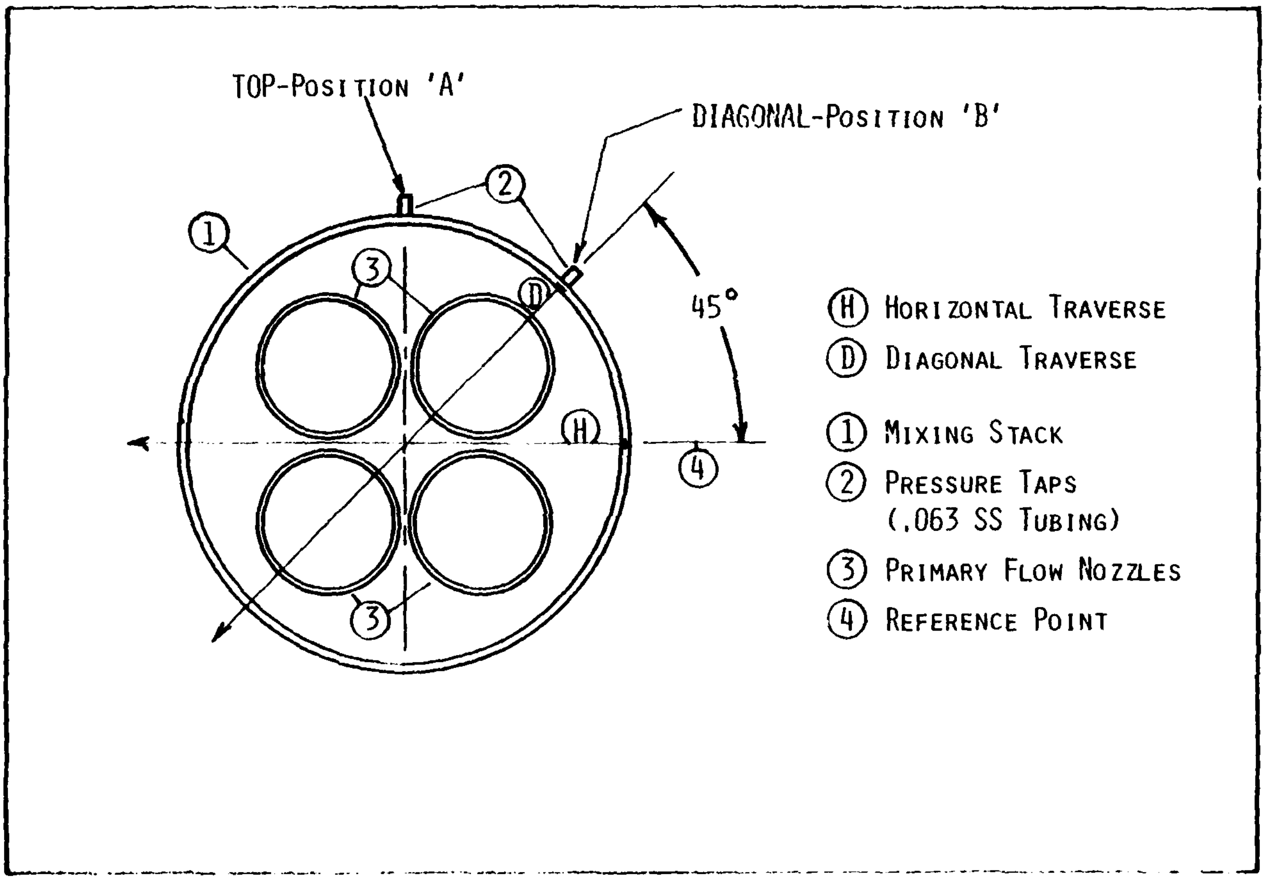



Figure 7. Mixing Stack Exit with Velocity Profile Directions and Pressure Tap Locations

FIGURE 8 - VELOCITY TRAVERSE BAR AND MIXING STACK

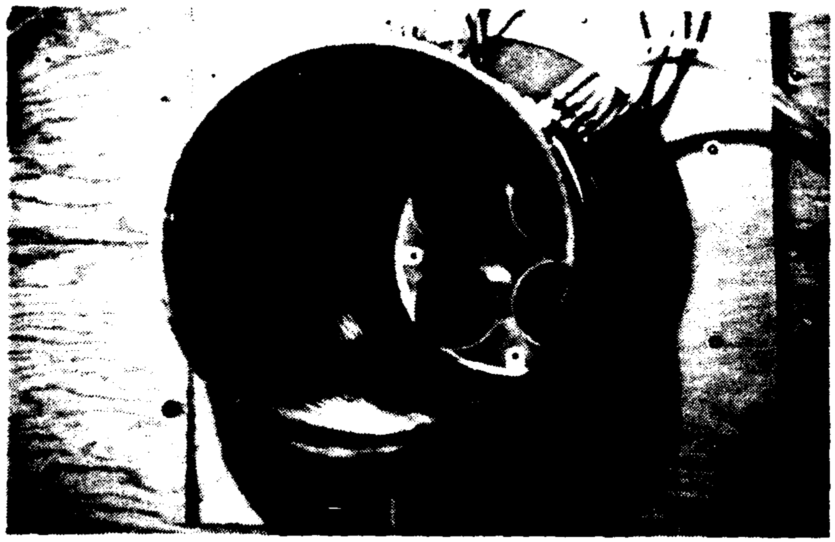


FIGURE 9 - MIXING STACK WITH PRESSURE TAPS AND AIR SEAL

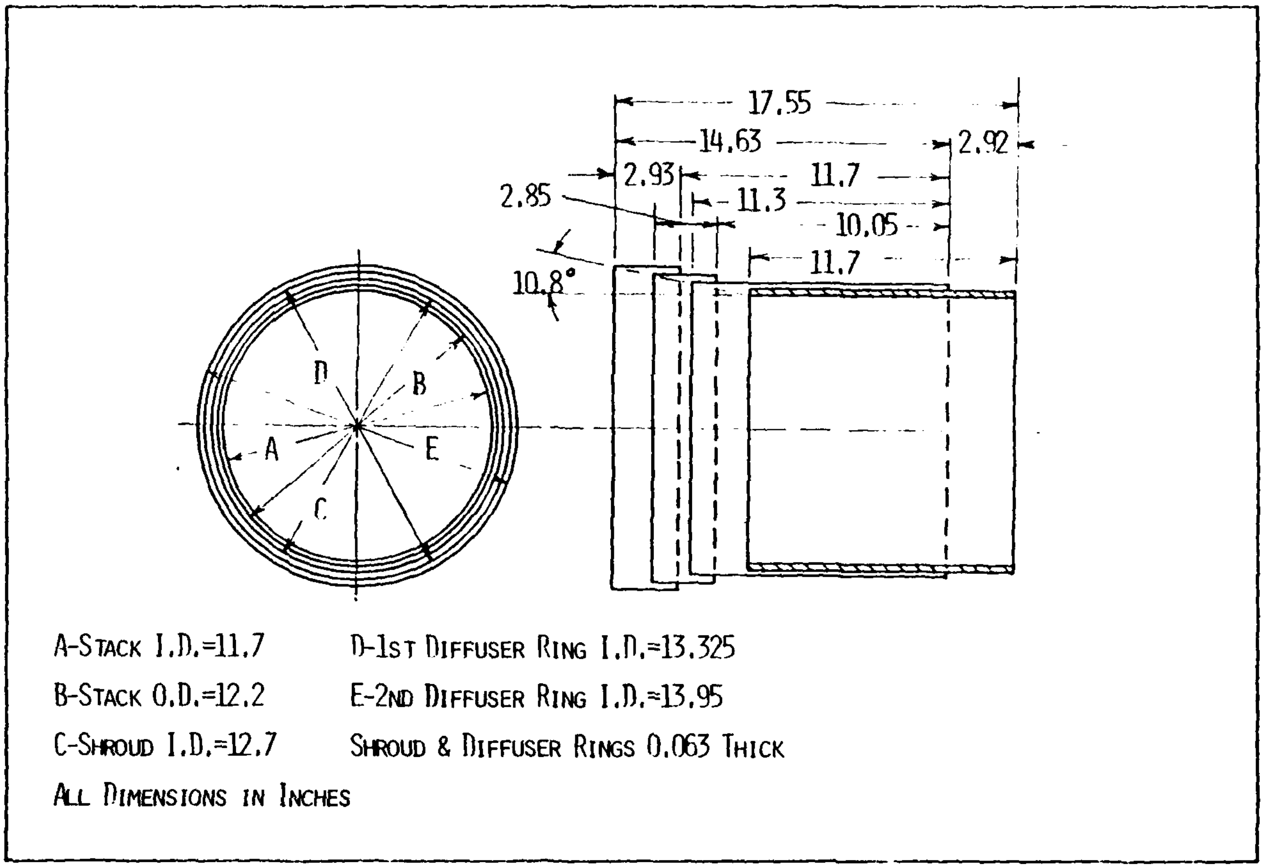



Figure 10. Schematic of 10.8 Degree Diffuser Angle Shroud

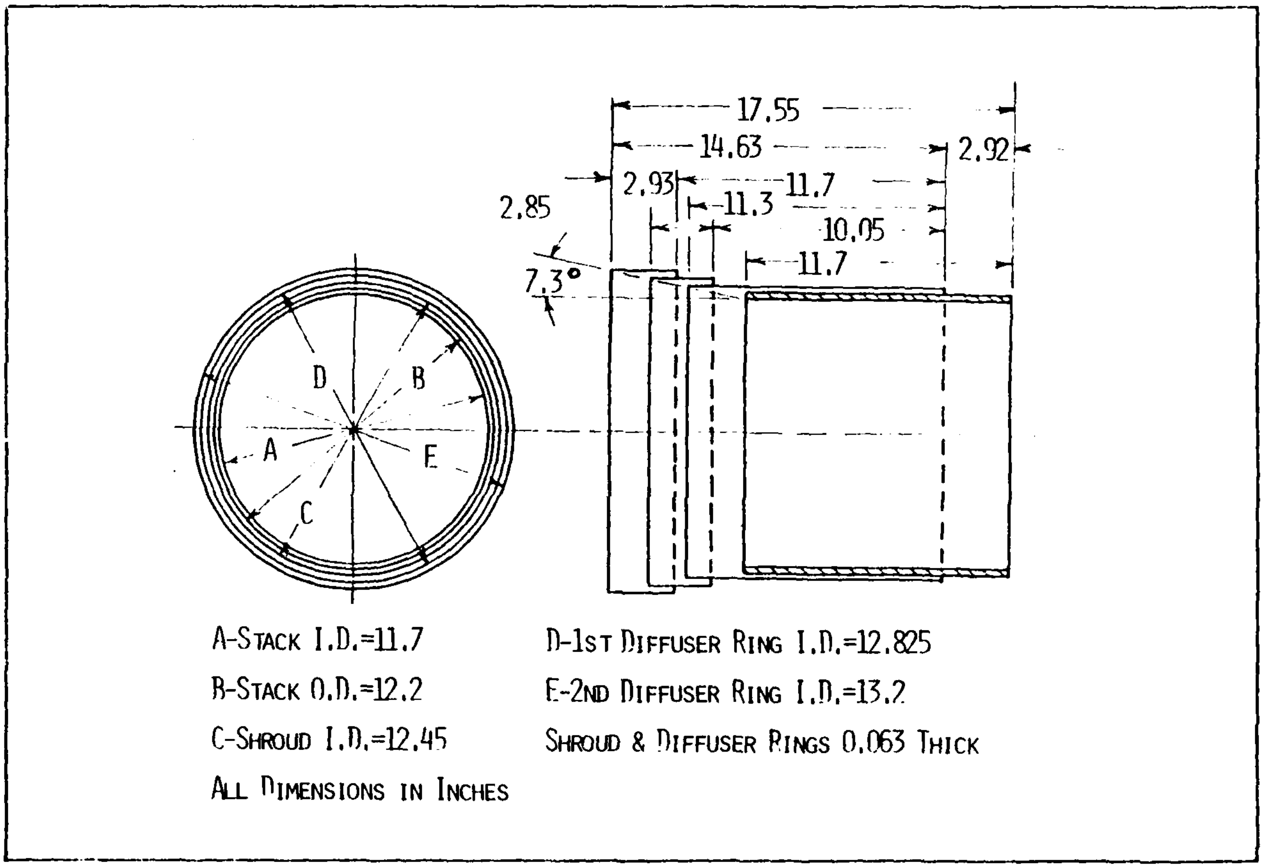



Figure 11. Schematic of 7.3 Degree Diffuser Angle Shroud

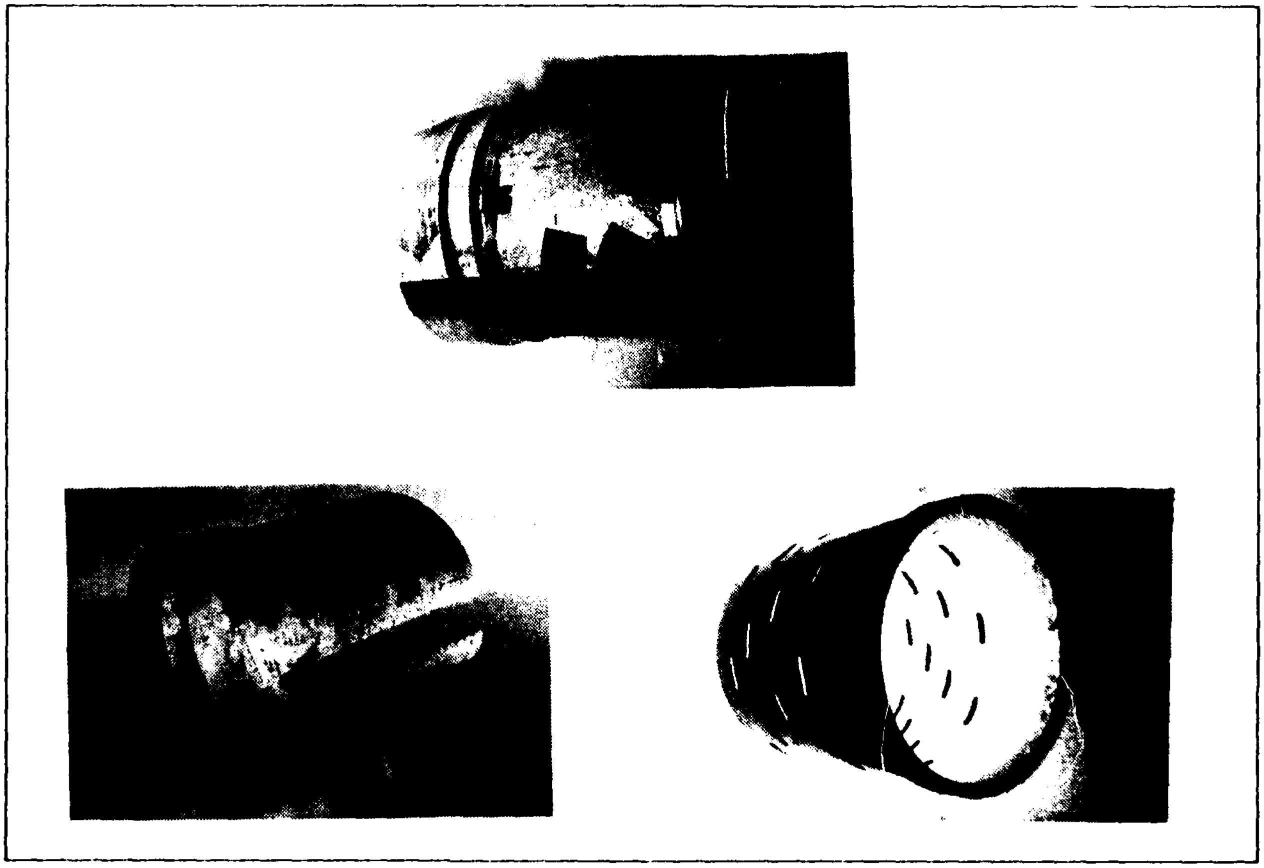
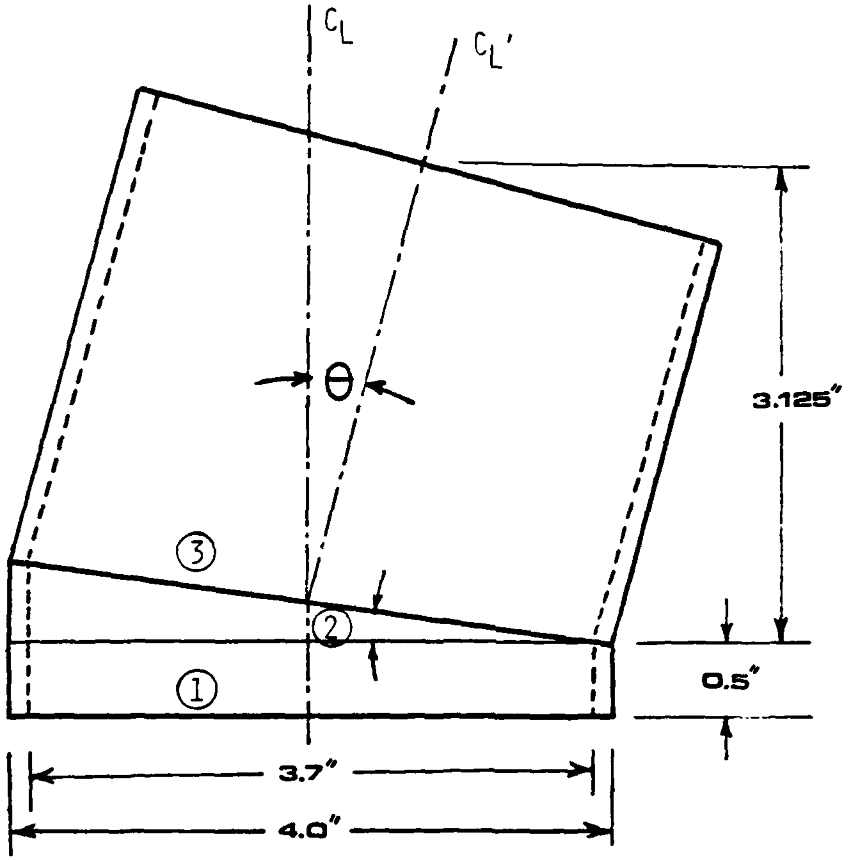


Figure 12. Slotted Mixing Stack and Shroud




(1) 0.5 INCH MACHINED SURFACE TO FIT THE NOZZLE BASE PLATE RECESSES

(2) MITER ANGLE-ONE -HALF OF THE TILT ANGLE

(3) CUT AND JUNCTURE LINE

NOZZLE TILT ANGLE($\Theta$)= 15 DEGREES

Figure 13. Dimensions of Primary Nozzles

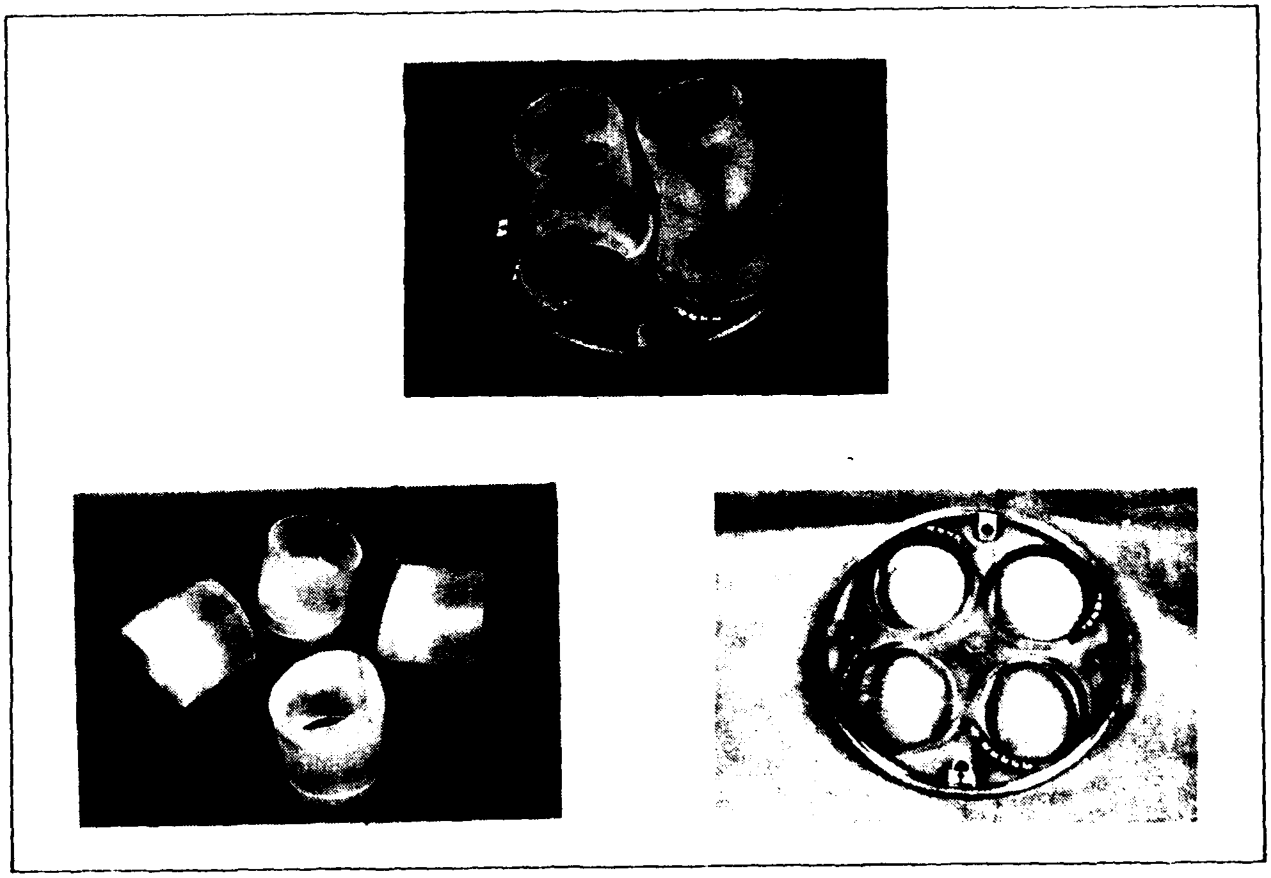


Figure 14. Angled Primary Nozzles and Base Plate

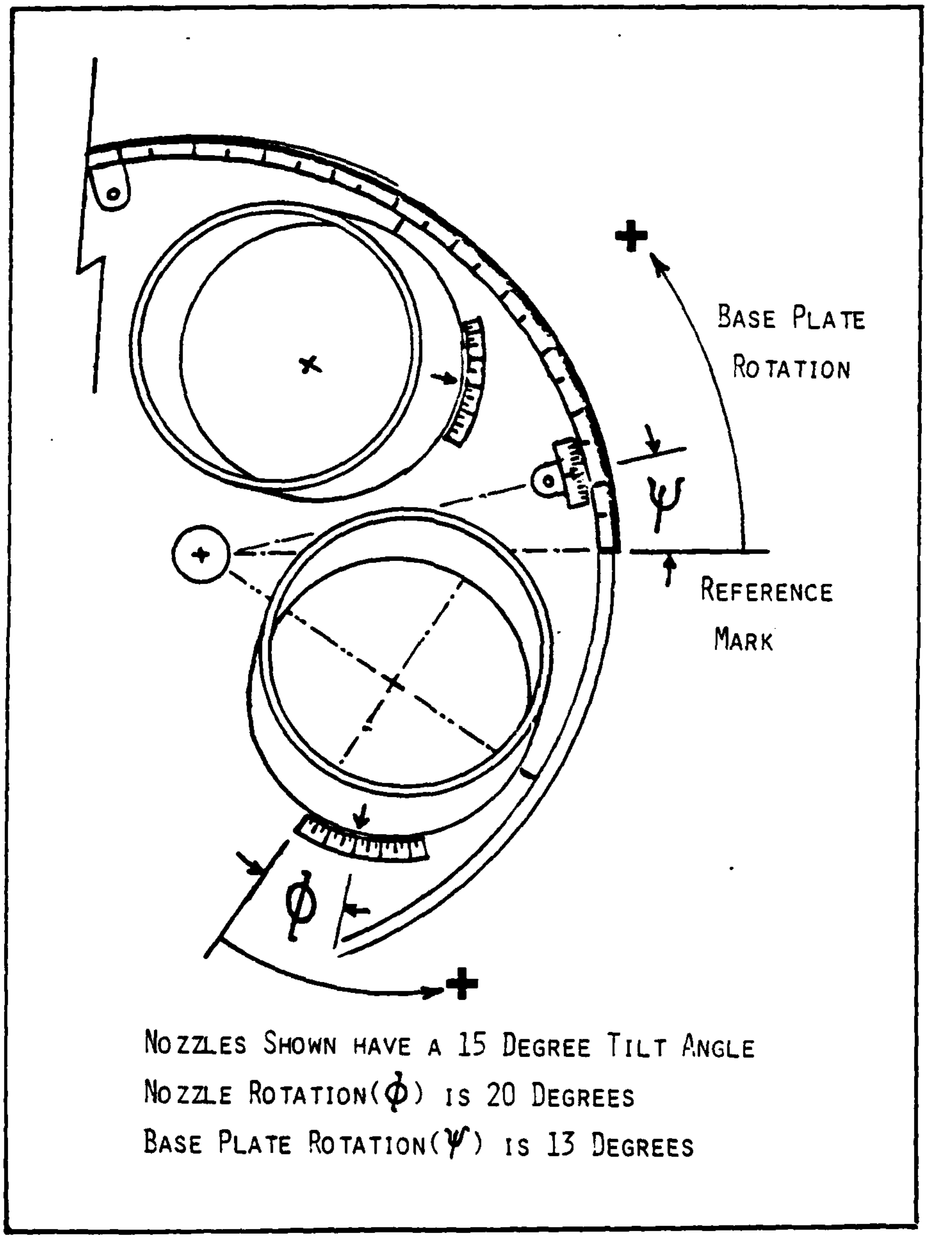



Figure 15. Base Plate and Nozzle Rotation Angles

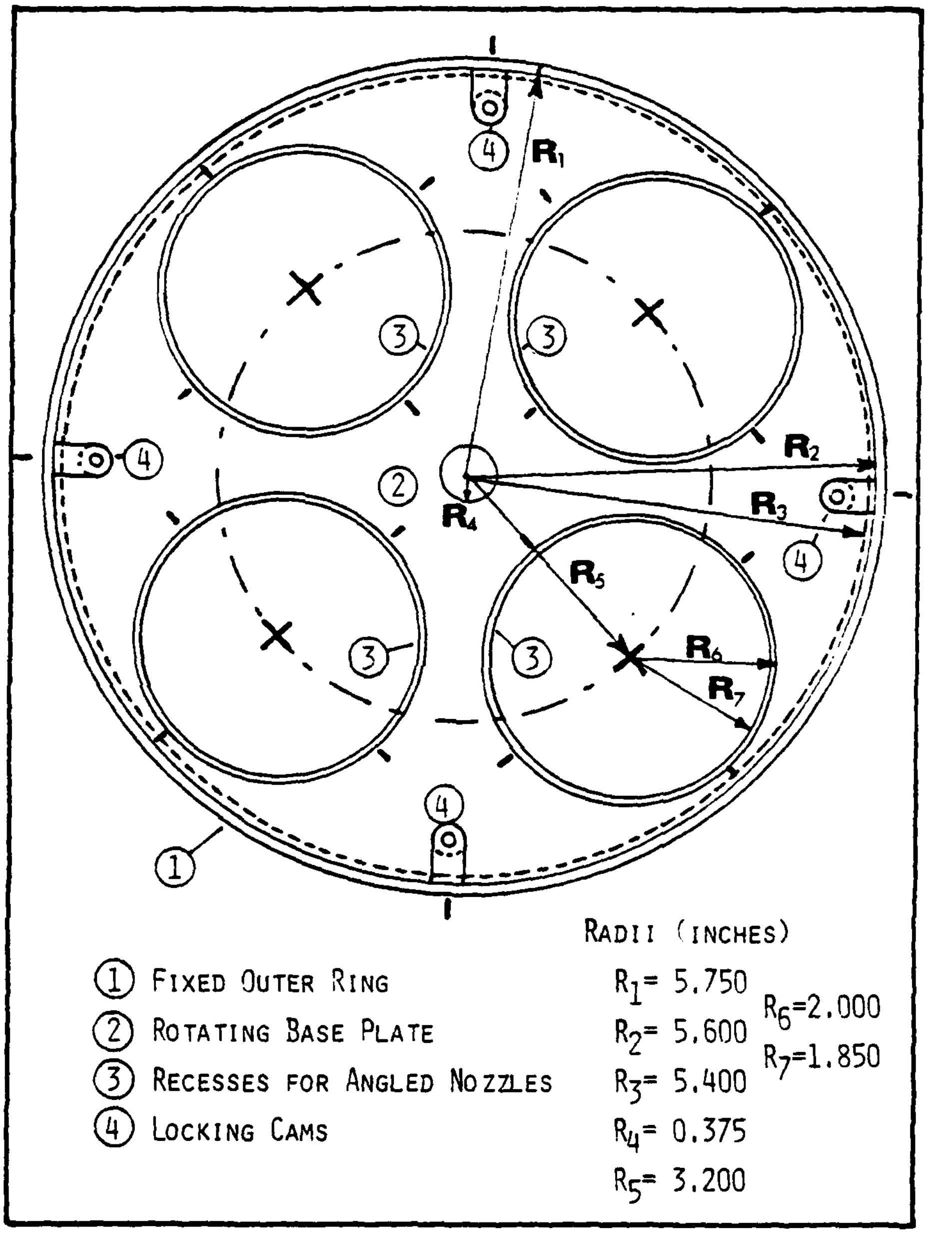



Figure 16. Dimensions for the Rotatable Nozzle Base Plate

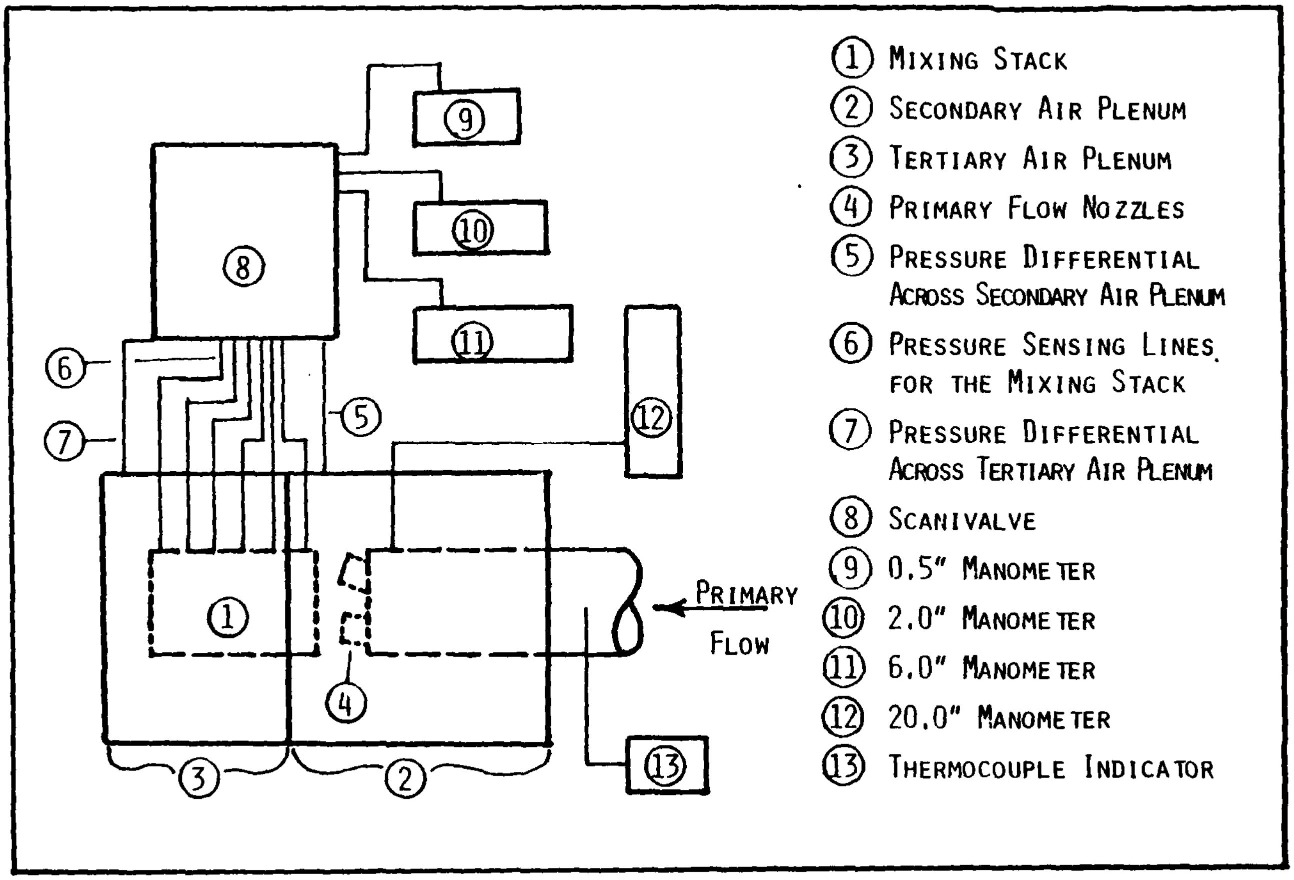



Figure 17. Schematic of Instrumentation

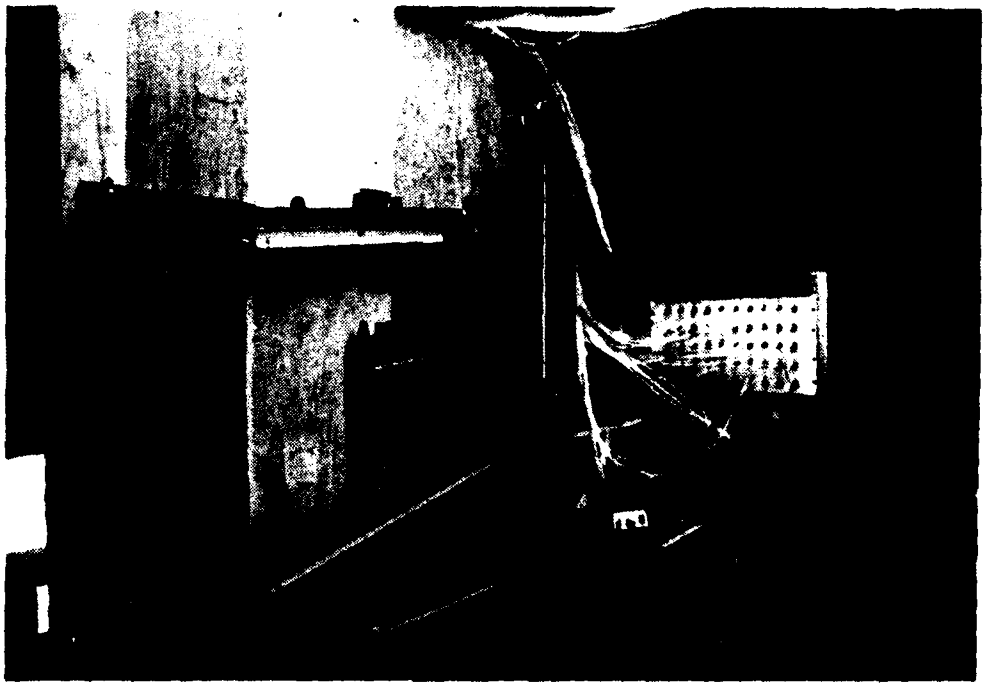


Figure 18. Instrumentation

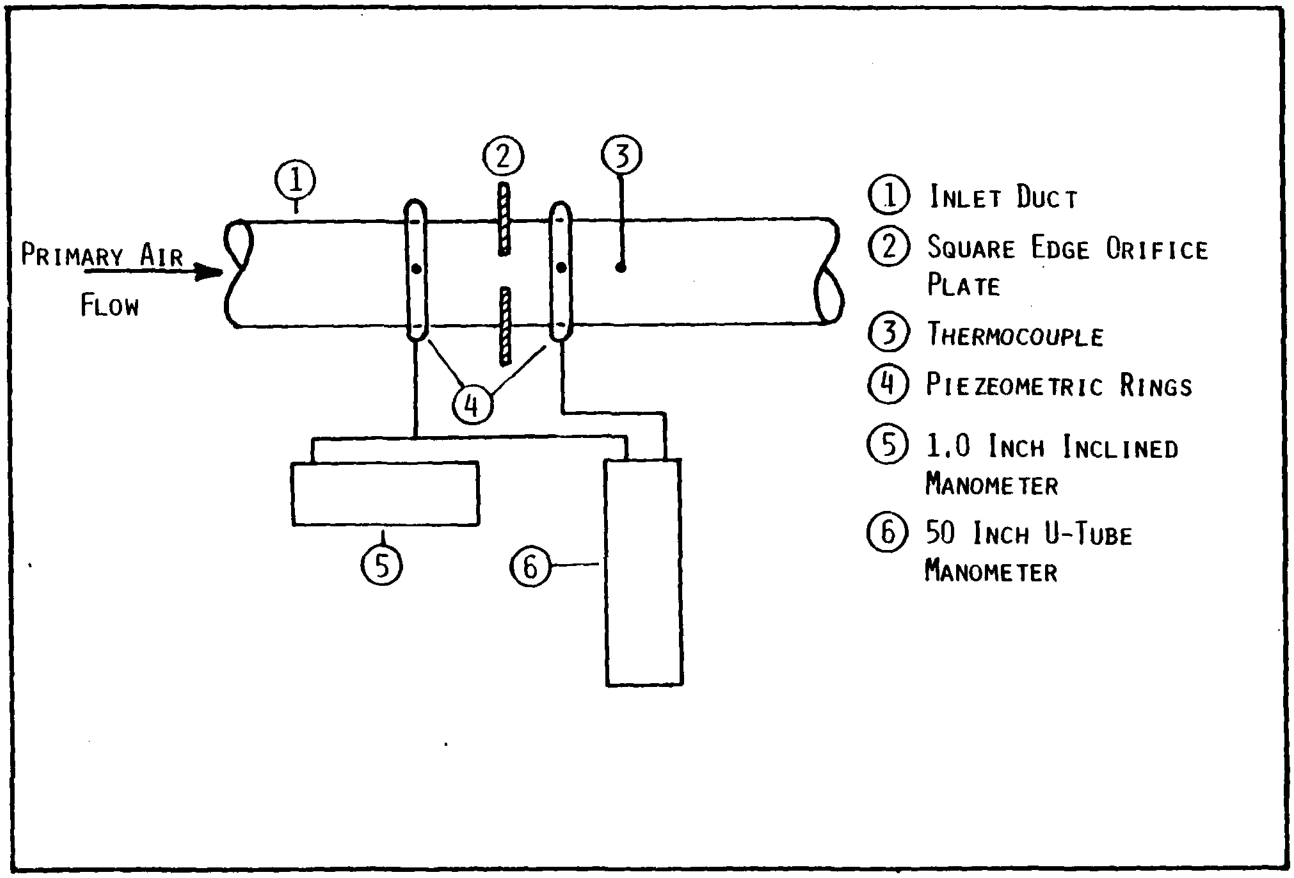



Figure 19. Schematic of Instrumentation for Primary Air Flow Measurement

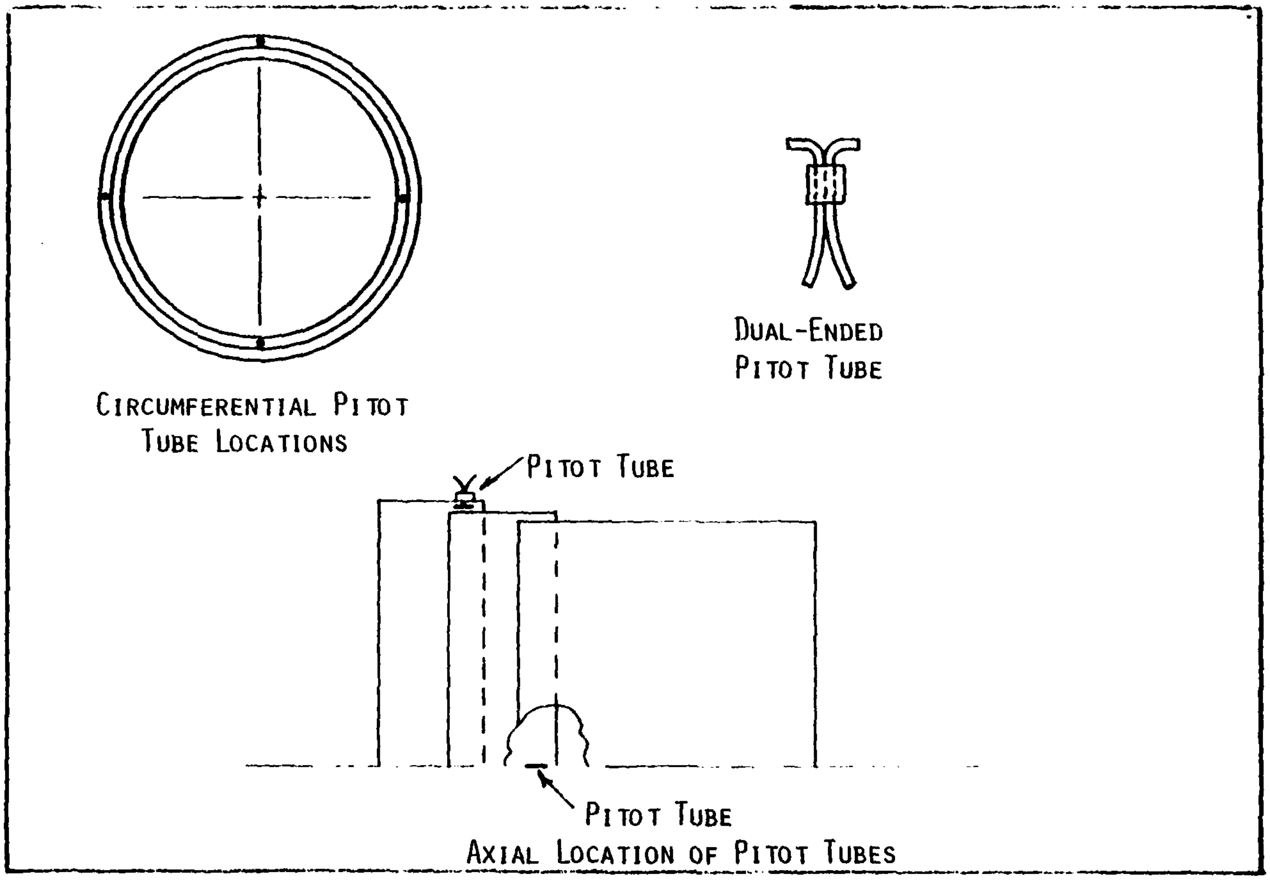



Figure 20. Dual Ended Pitot Tube Locations

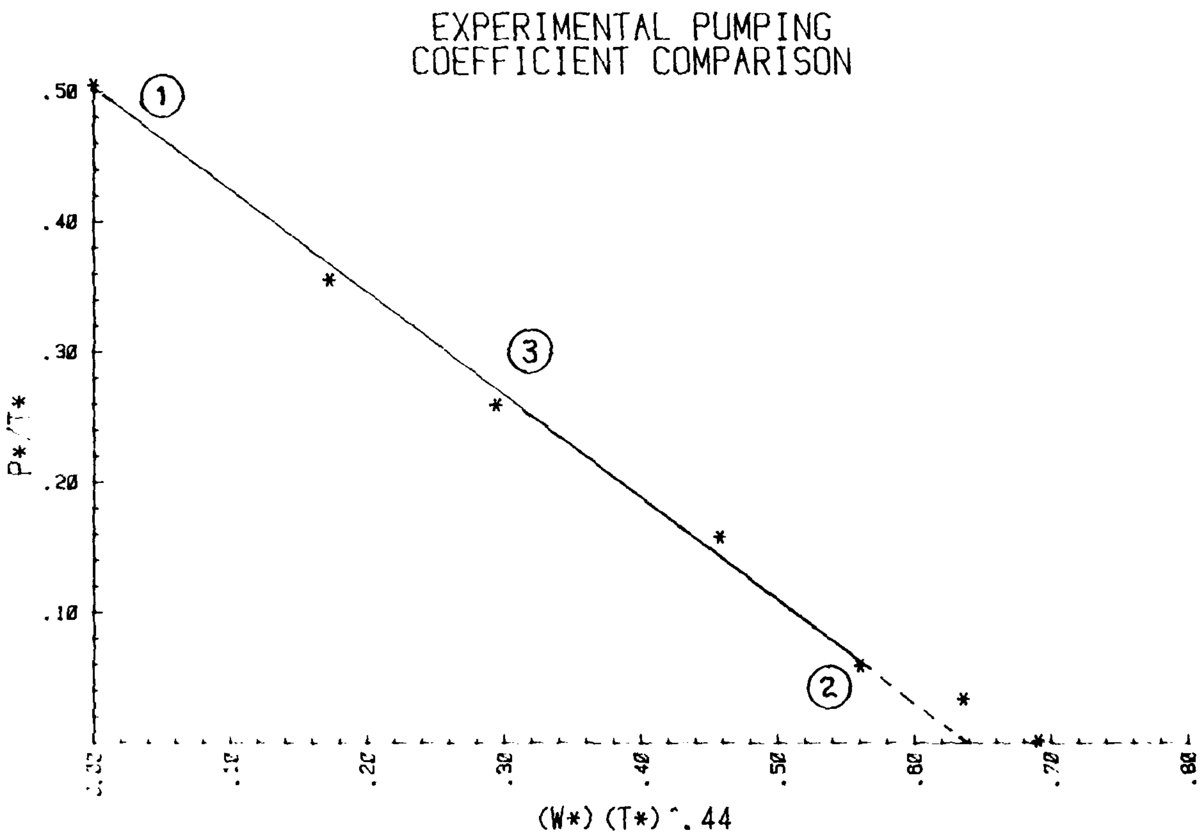



Figure 21. Sample Pumping Coefficient Plot

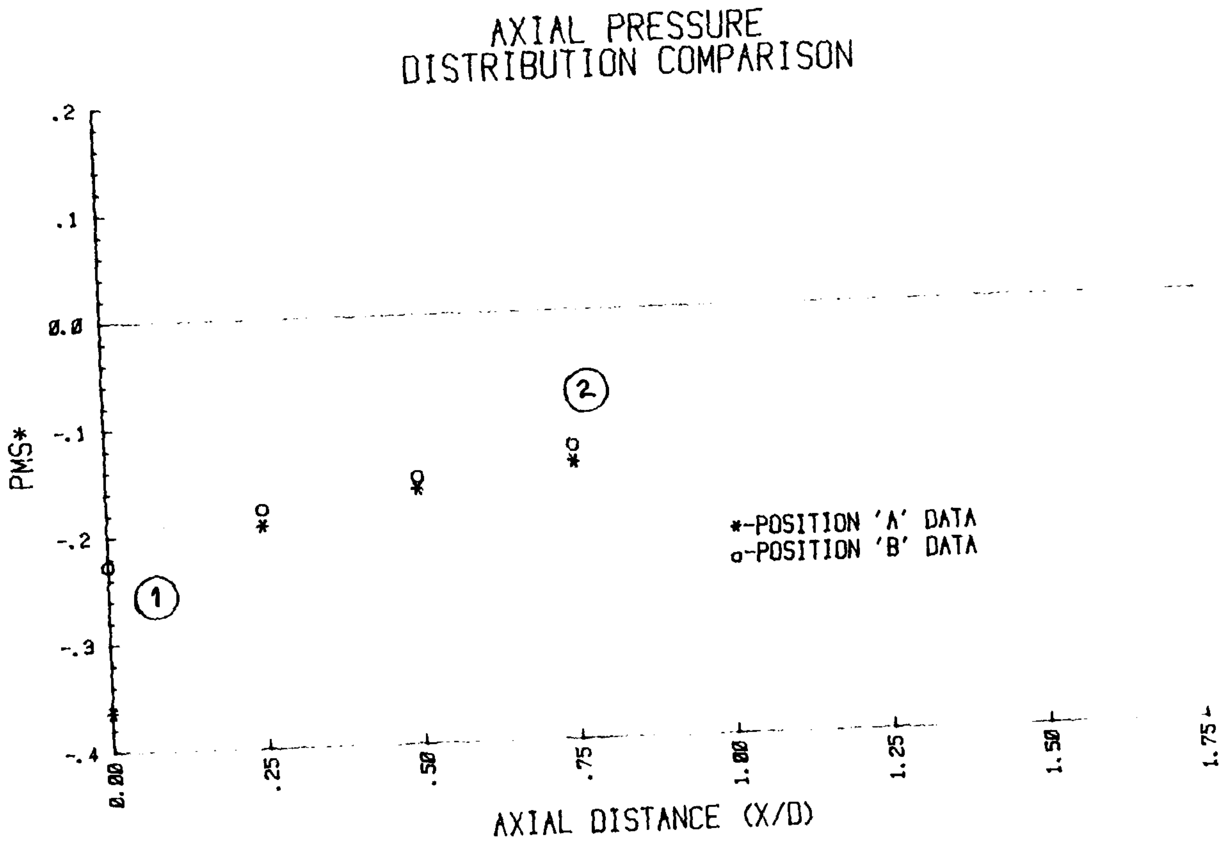



Figure 22. Sample Mixing Stack Pressure Distribution Plot

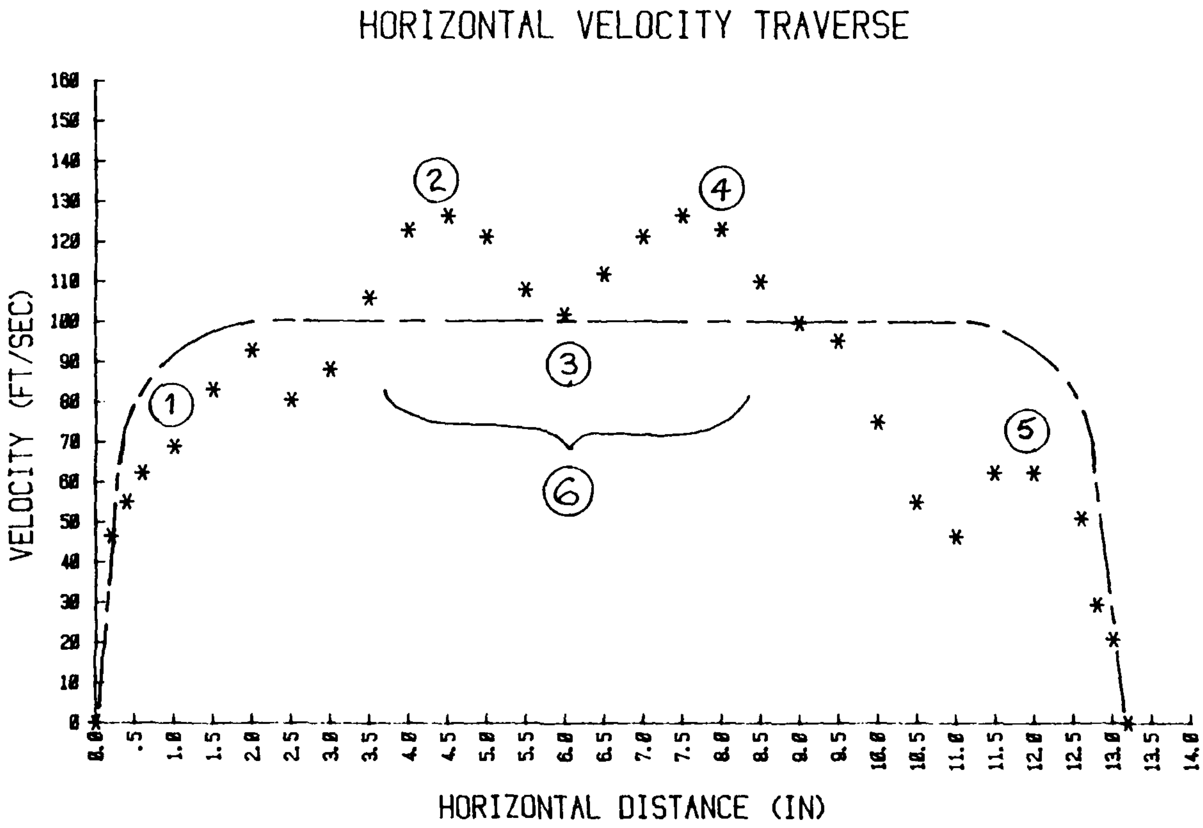



Figure 23. Sample Horizontal Velocity Profile Plot

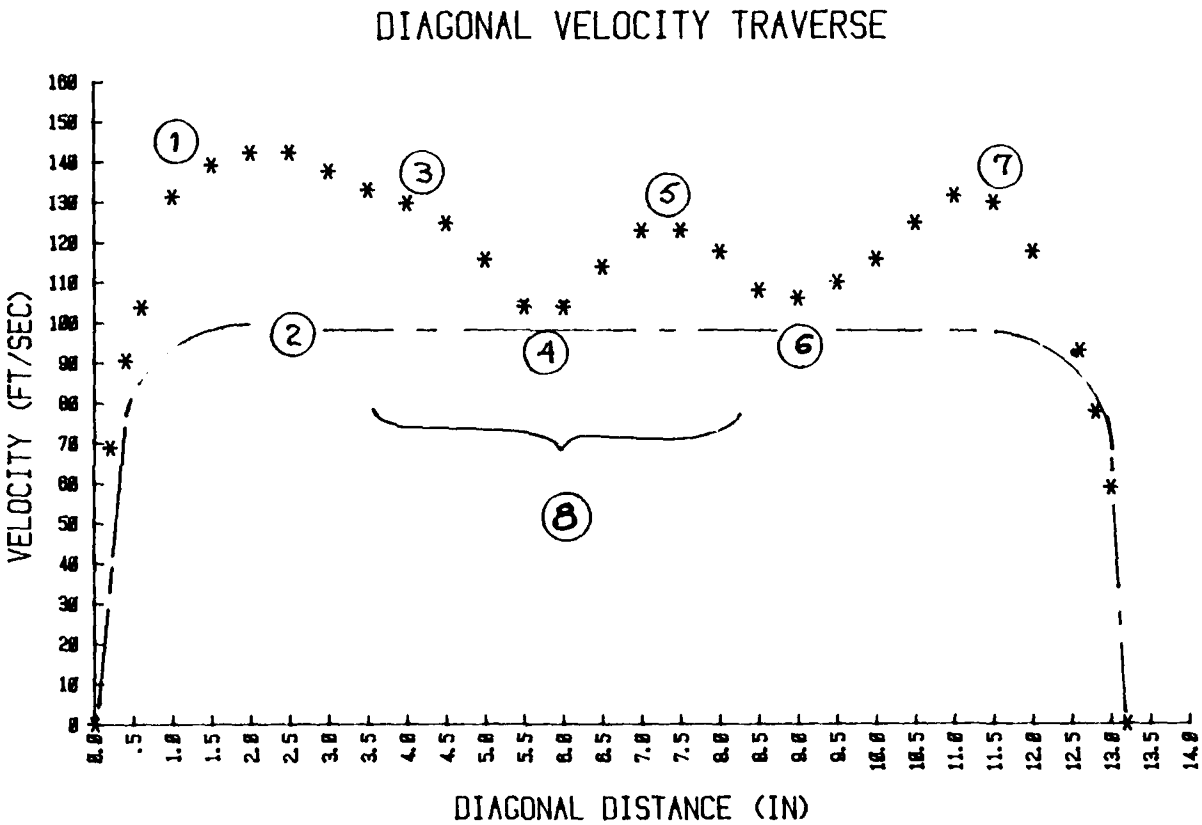



Figure 24. Sample Diagonal Velocity Profile Plot

AD-A116 304 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 21/5
CHARACTERISTICS OF A FOUR-NOZZLE, SLOTTED SHORT MIXING STACK WI--ETC(U)
MAR 82 C J DRUCKER

UNCLASSIFIED NL

2 of 3

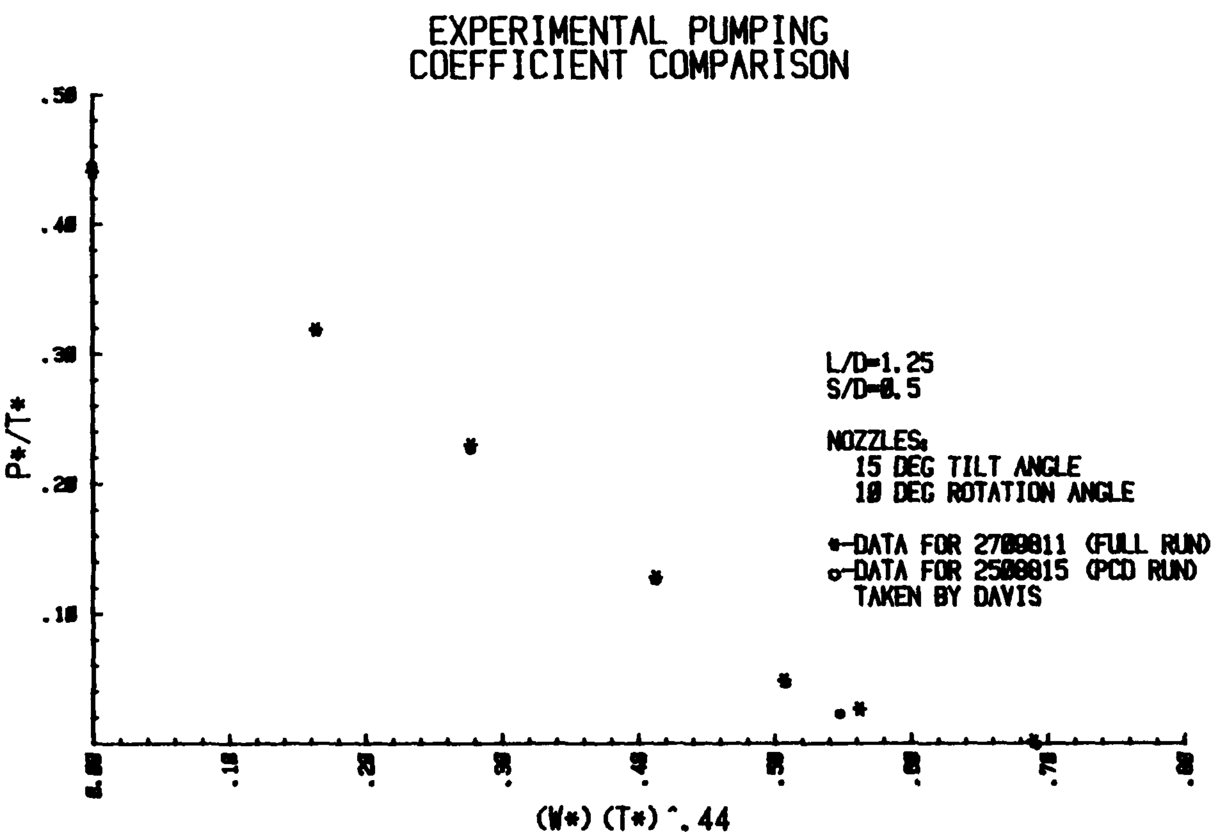



Figure 25. 15/10 Nozzles (Full Run)

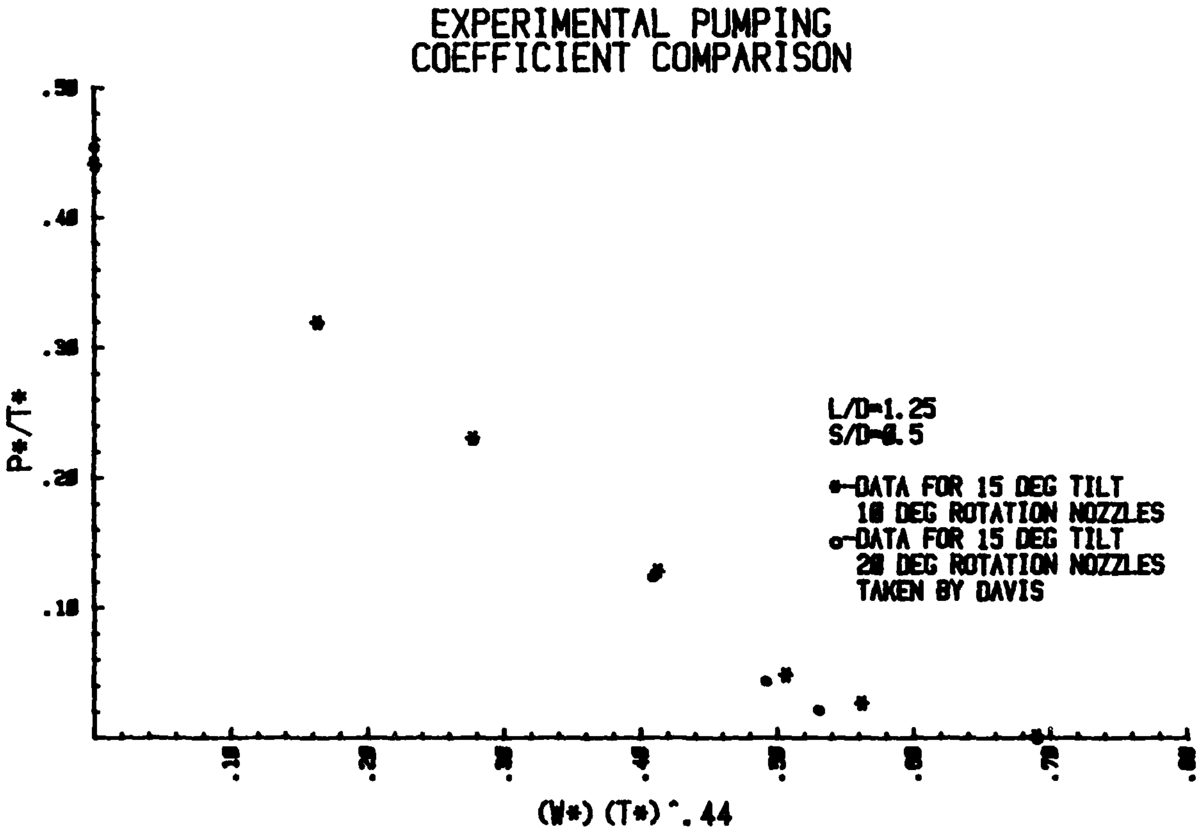



Figure 25. PCD

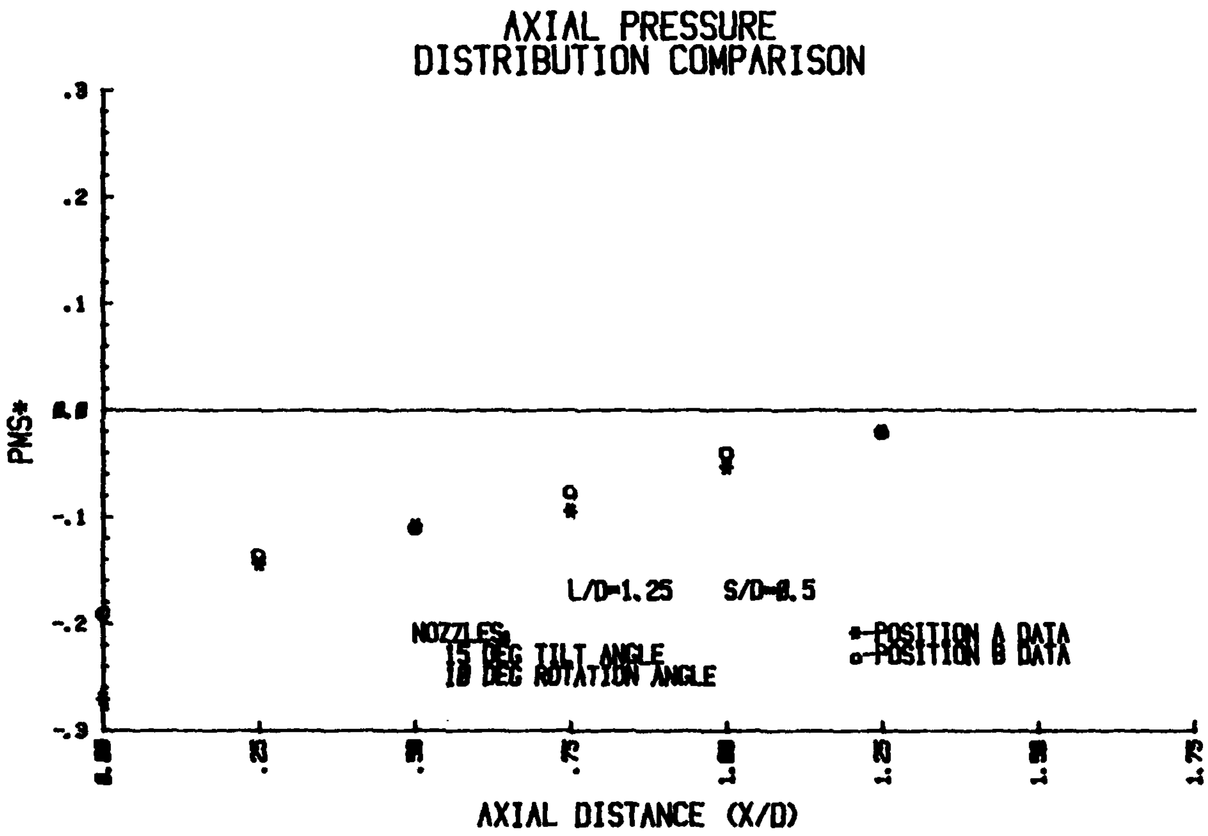



Figure 25. MSD

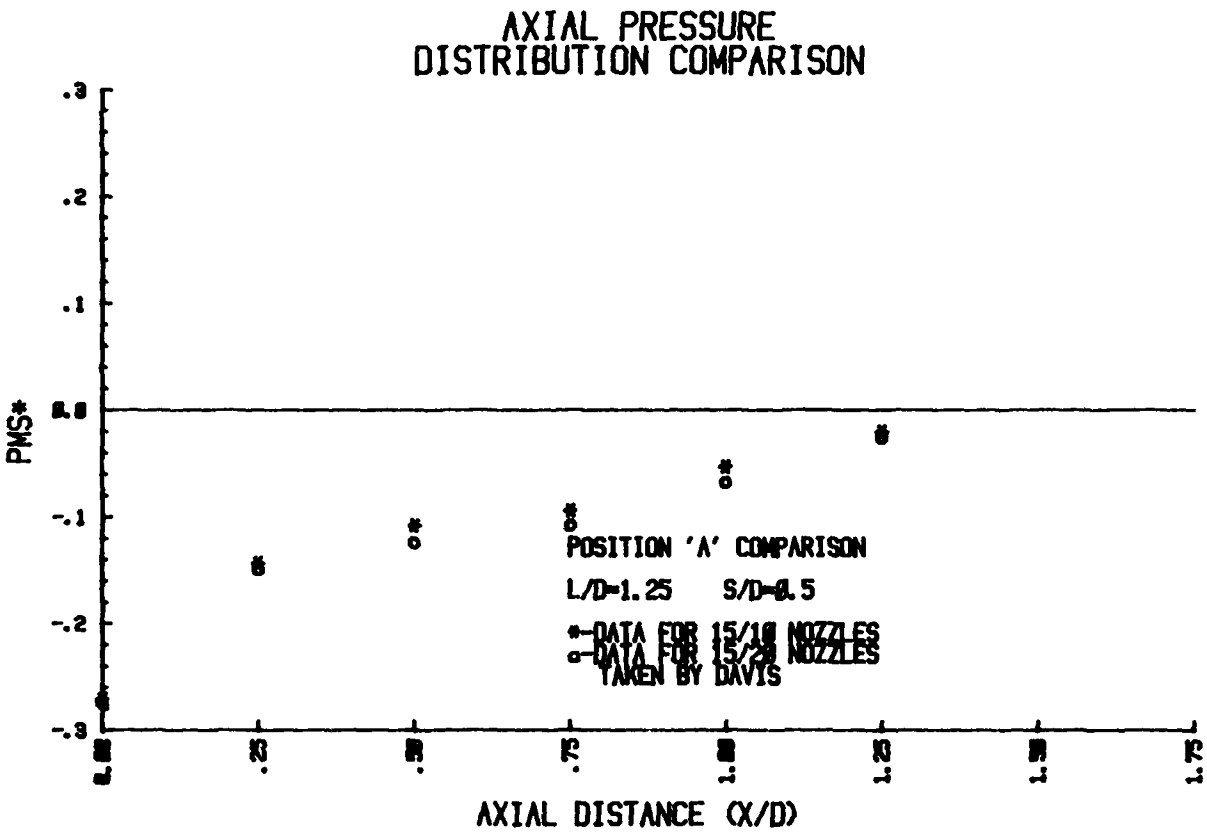



Figure 25. MSD

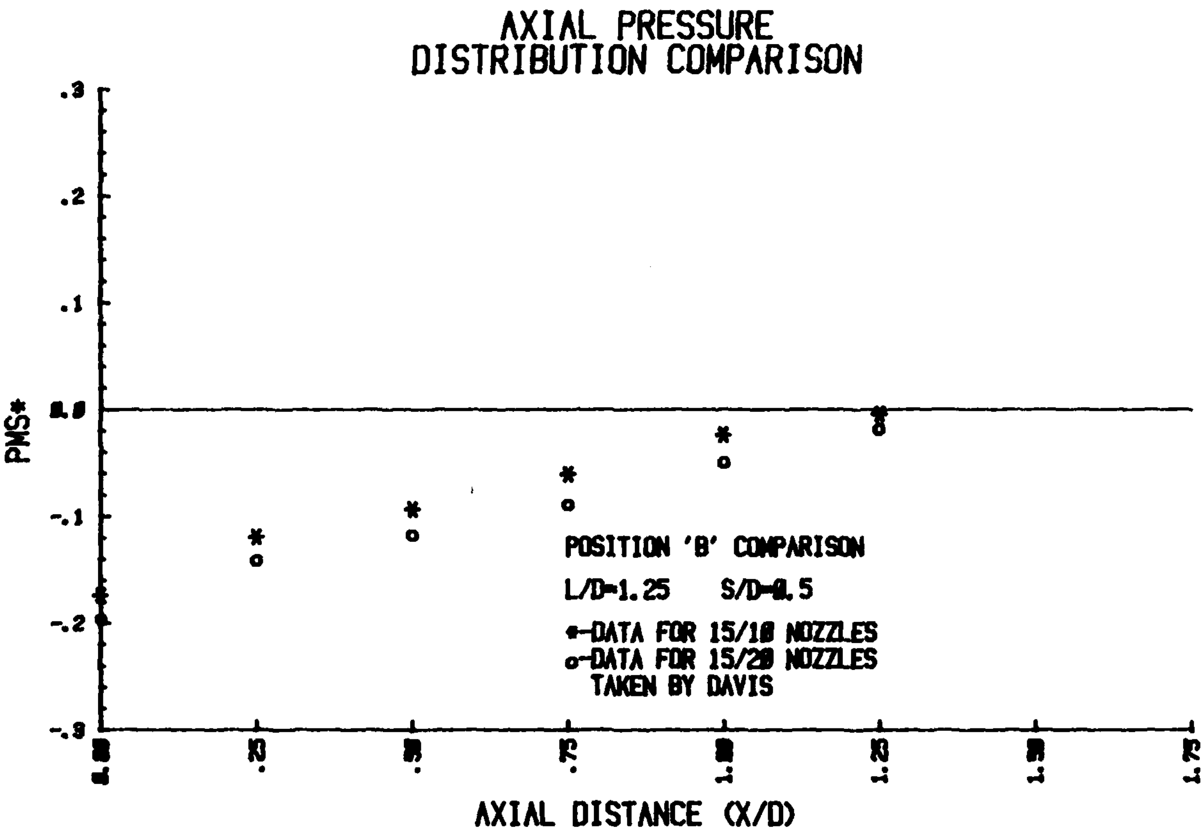



Figure 25. MSD

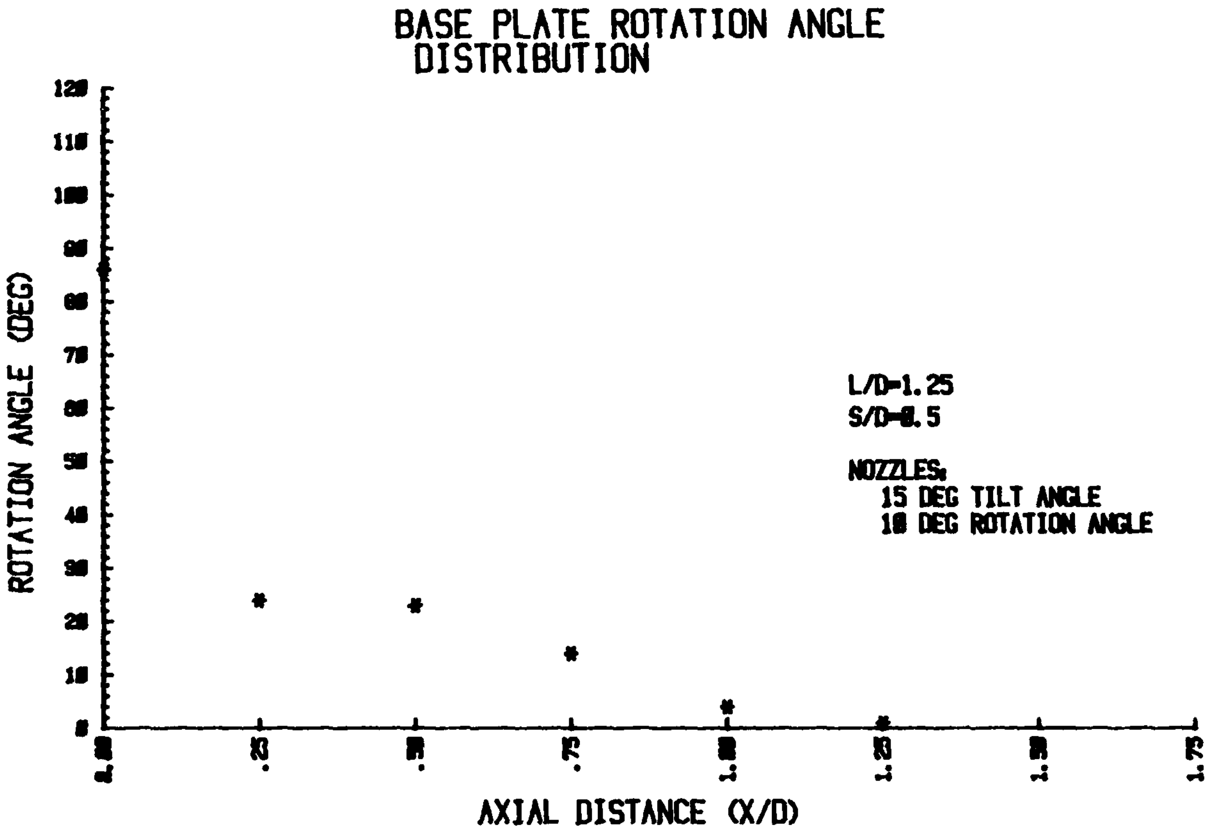



Figure 25. MSD

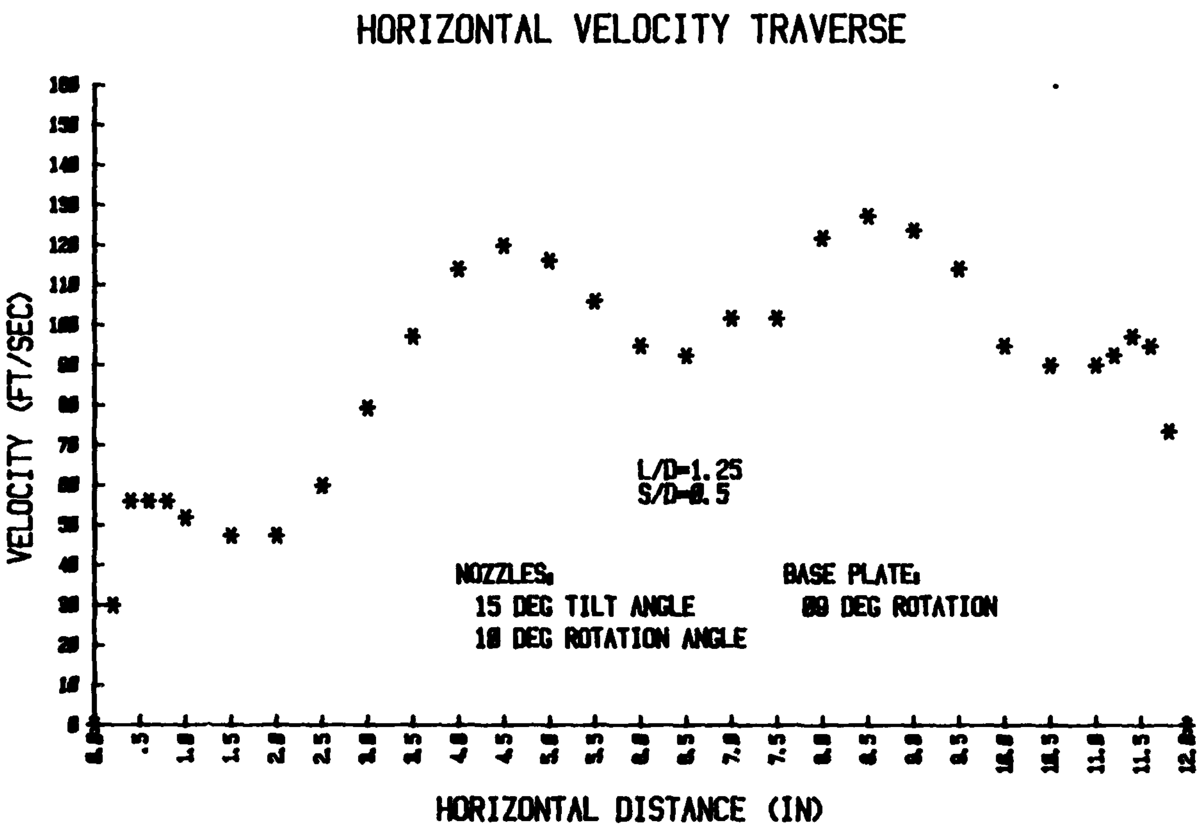



Figure 25. VTD

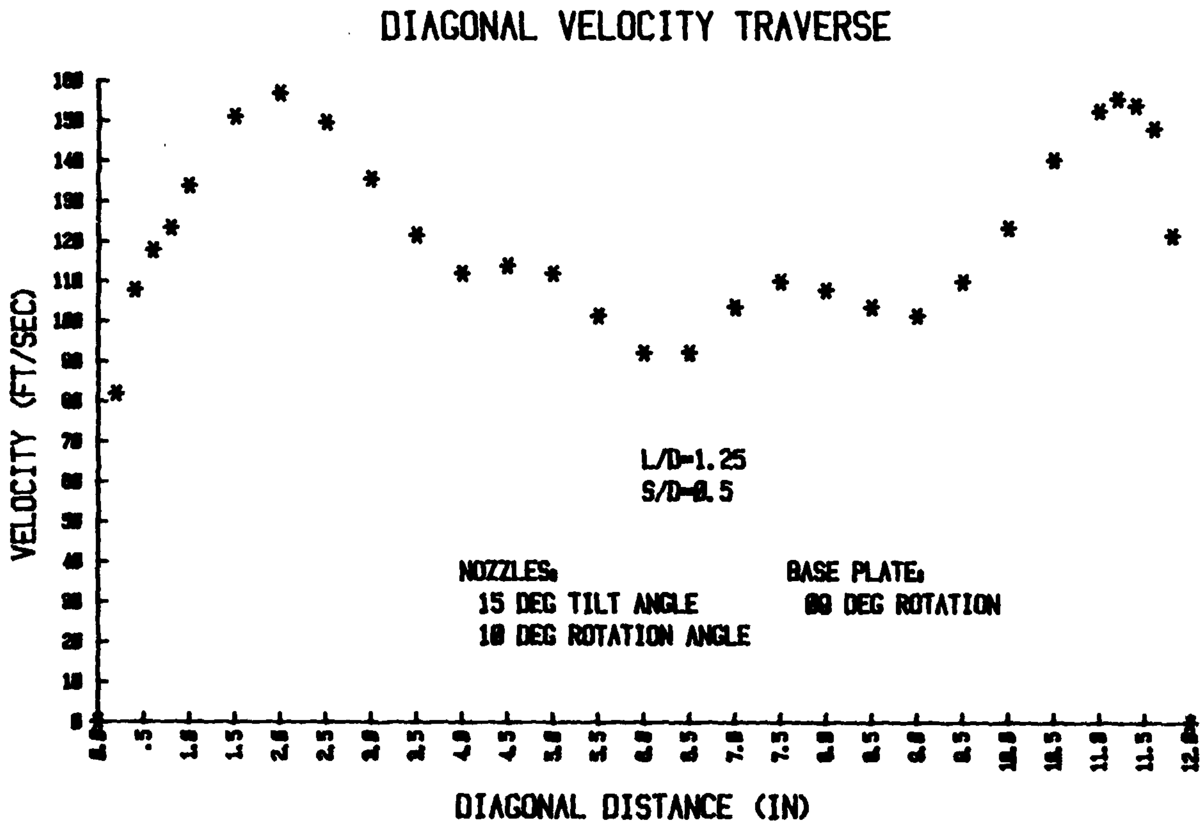



Figure 25. VTD

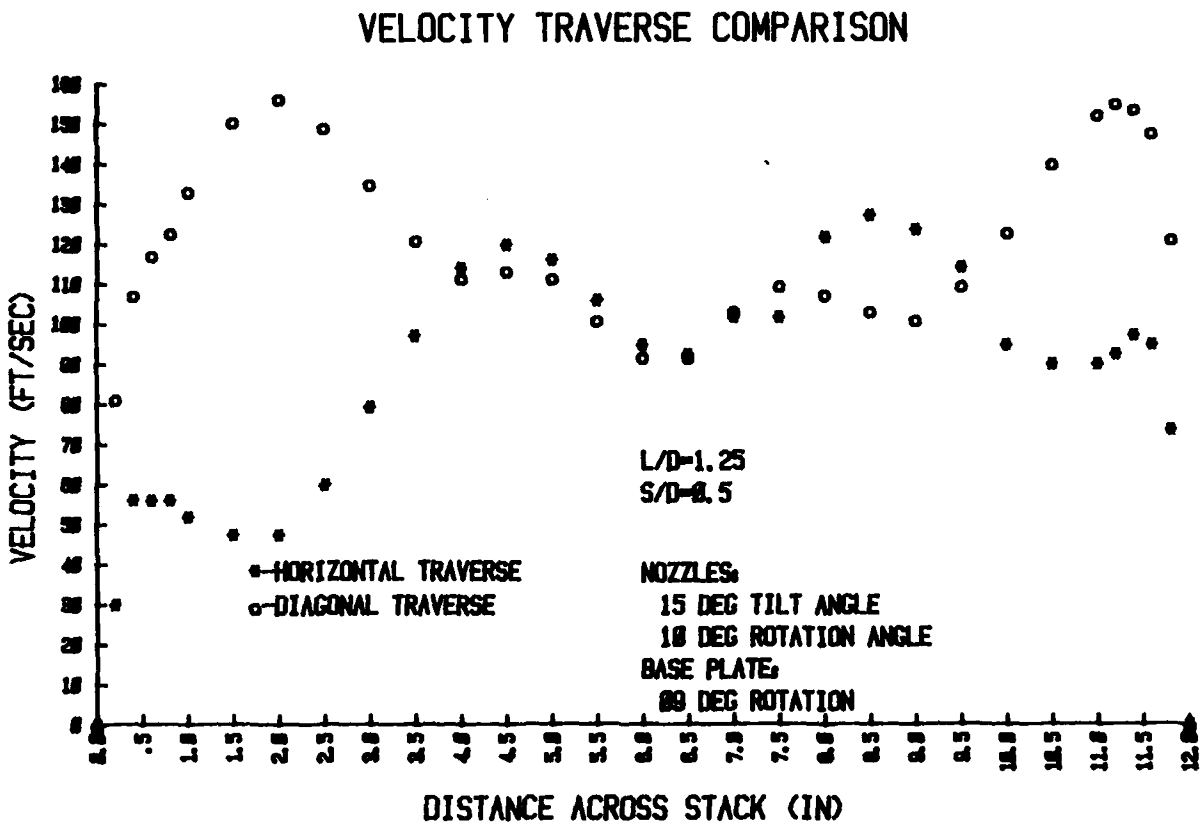



Figure 25. VTD

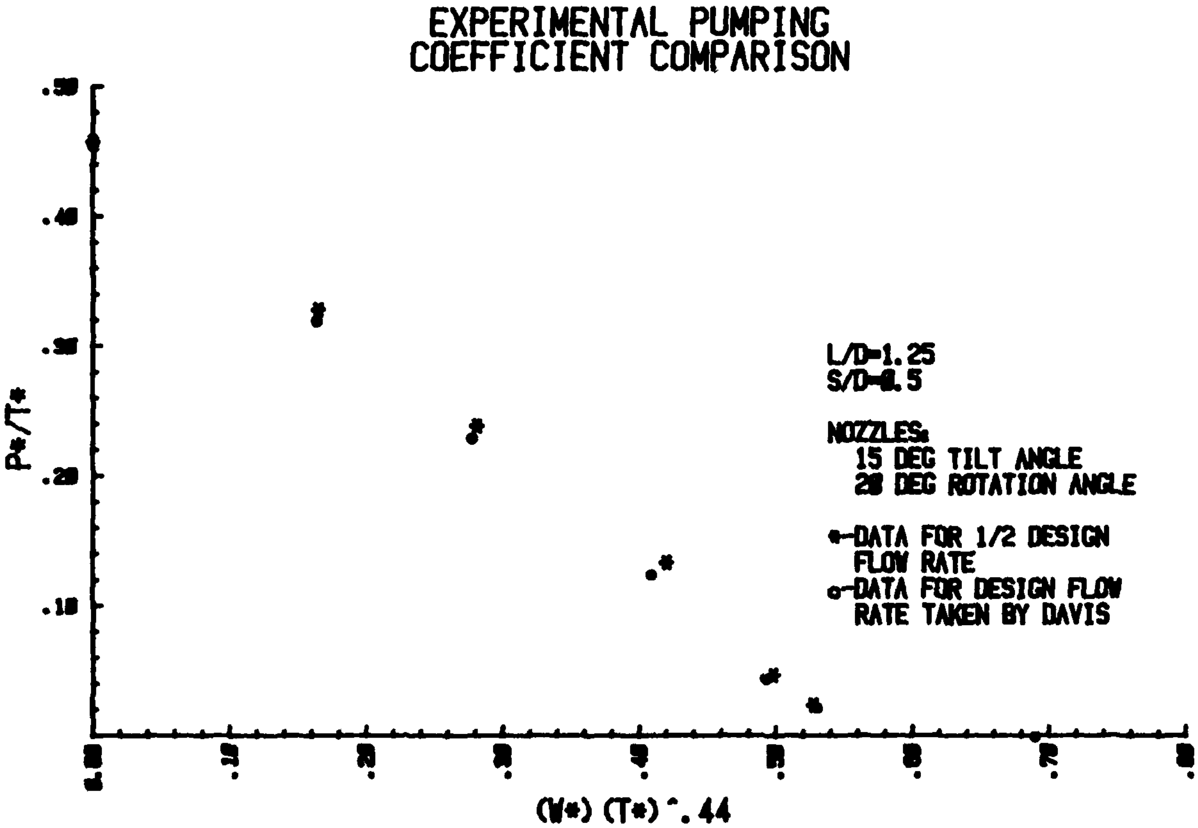



Figure 26. 50 Percent Design Flow

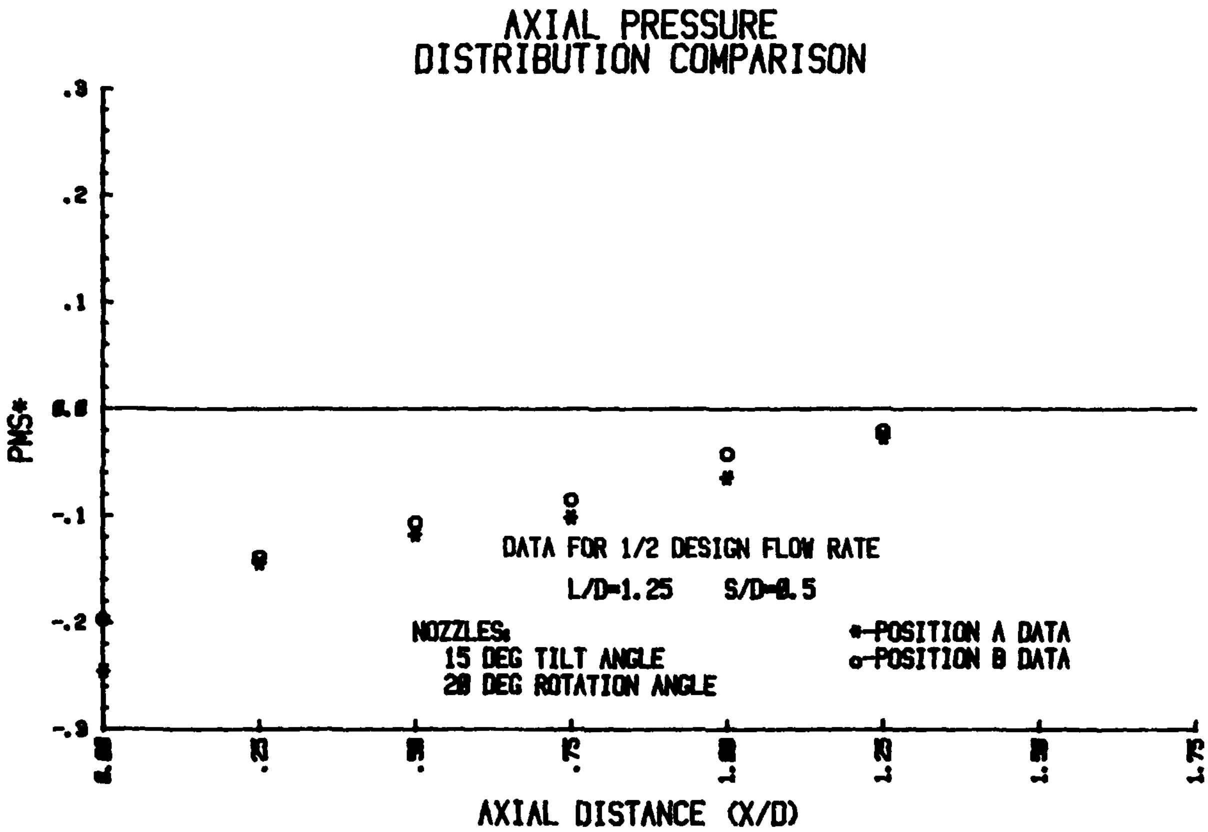



Figure 26. MSD

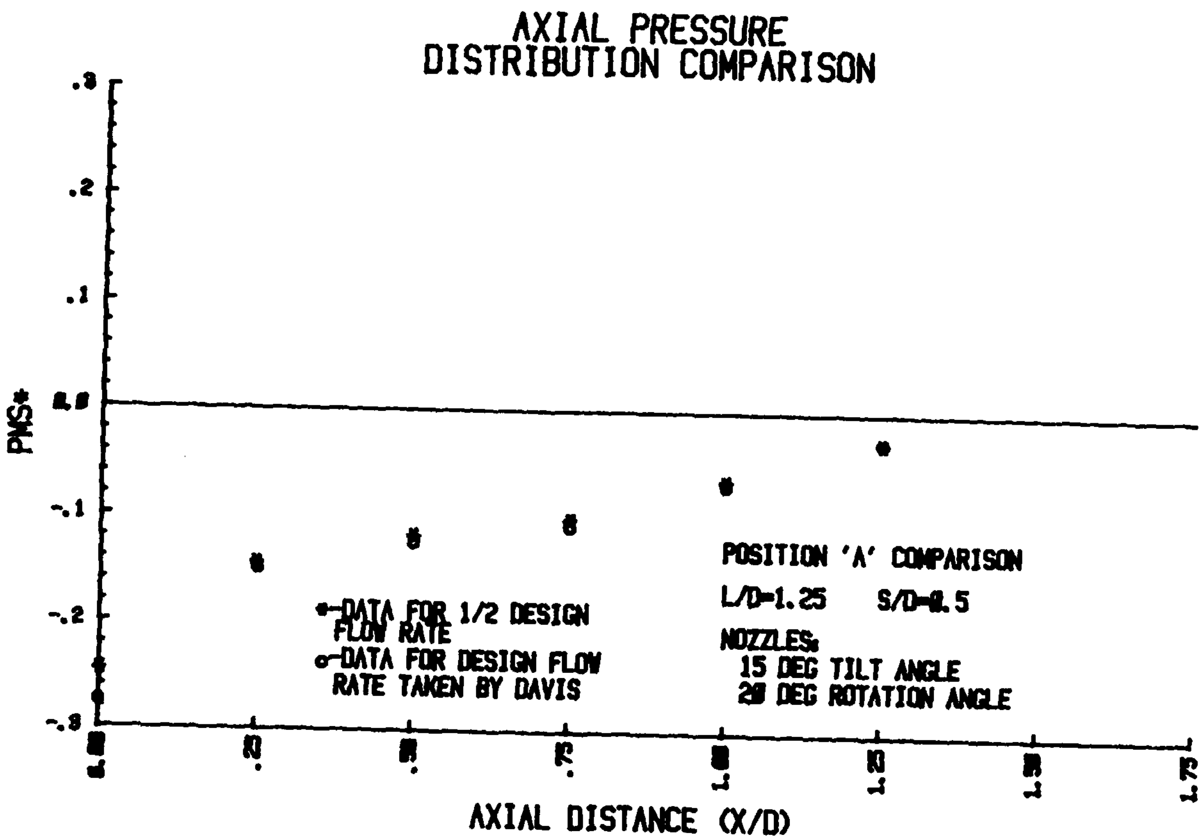



Figure 26. MSD

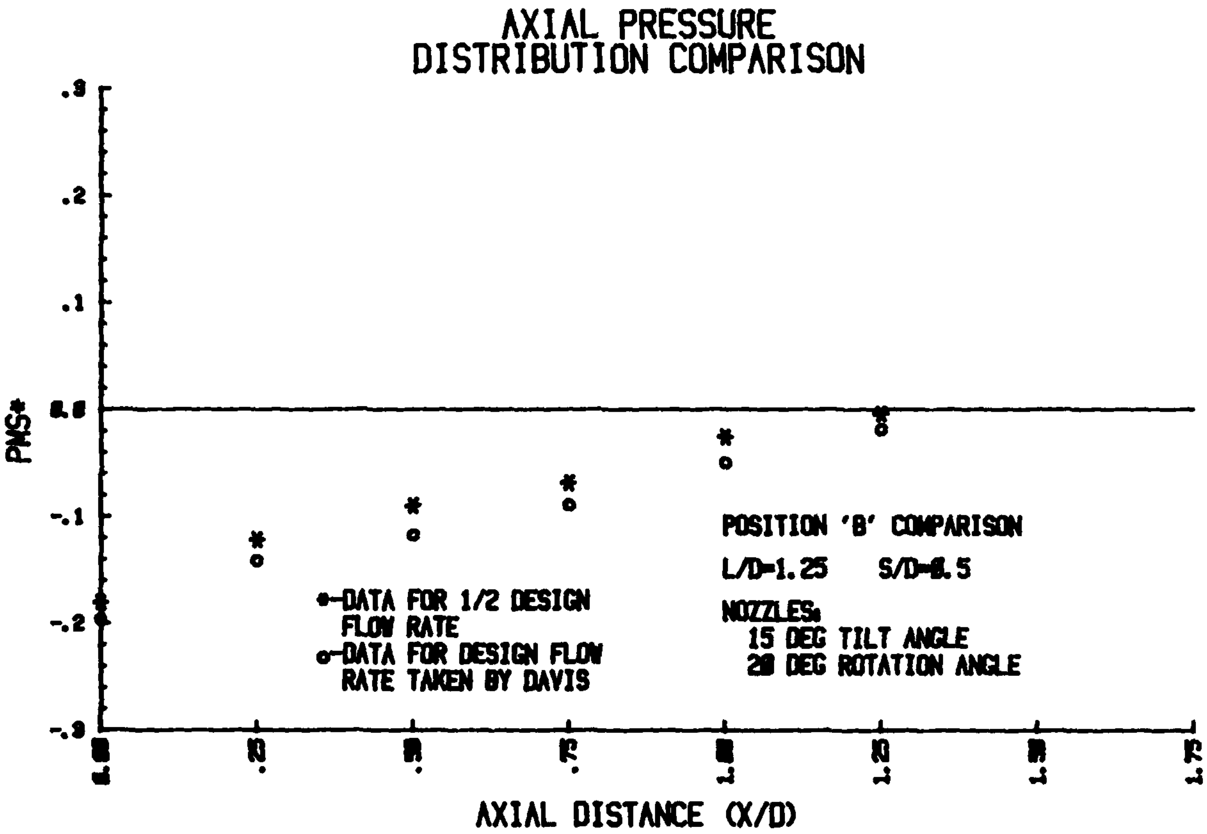



Figure 26. MSD

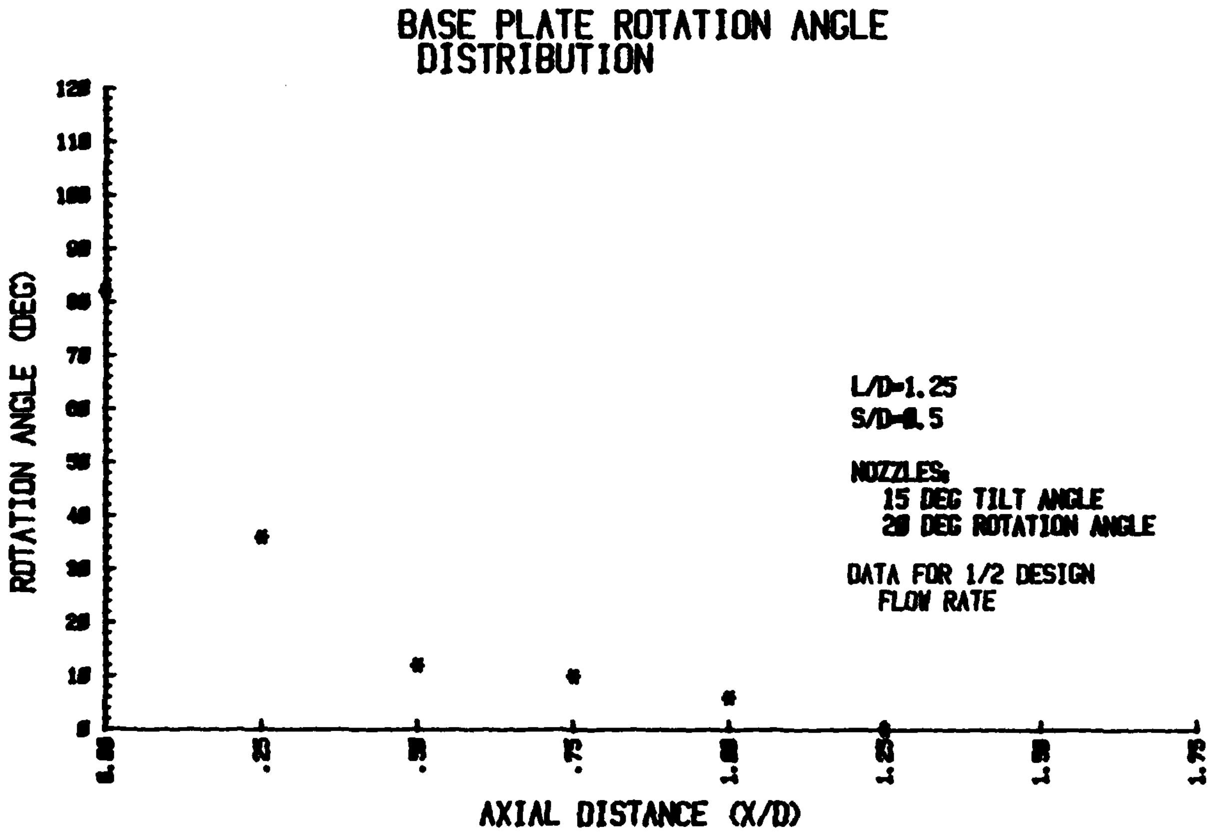



Figure 26. MSD

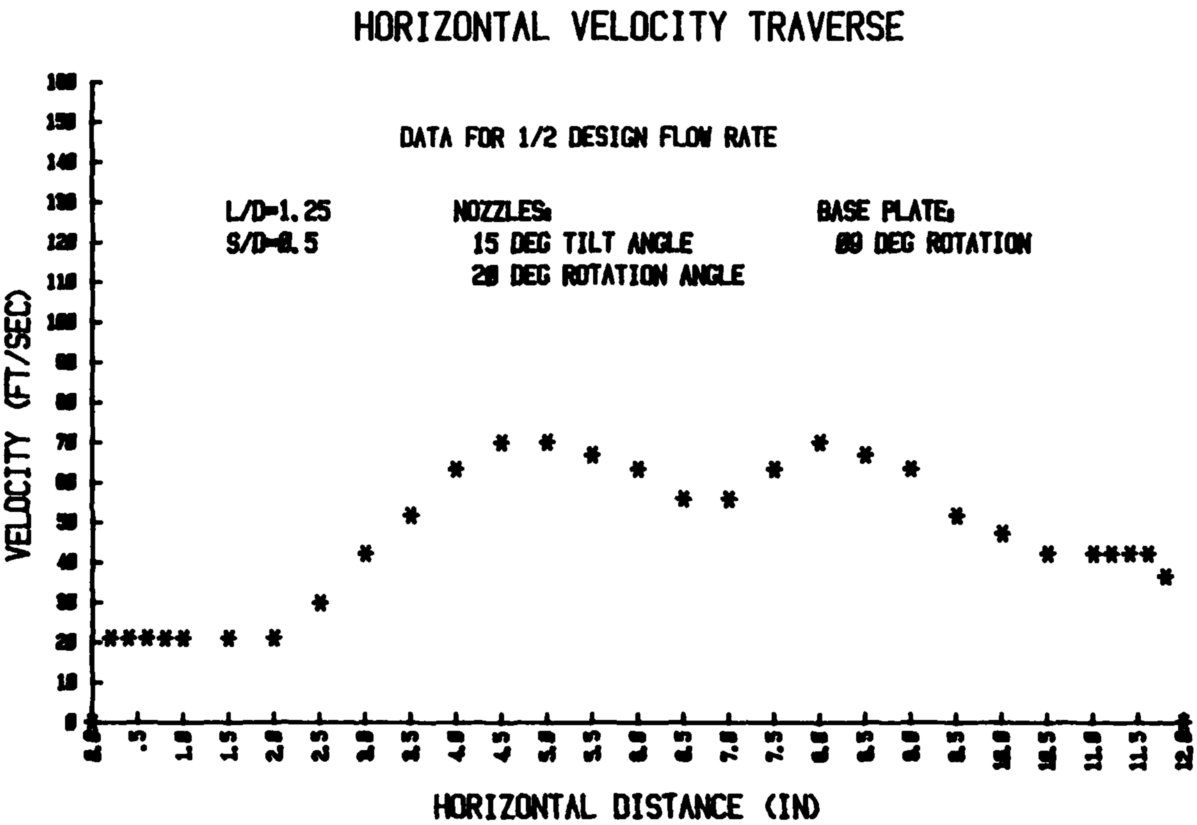



Figure 26. VTD

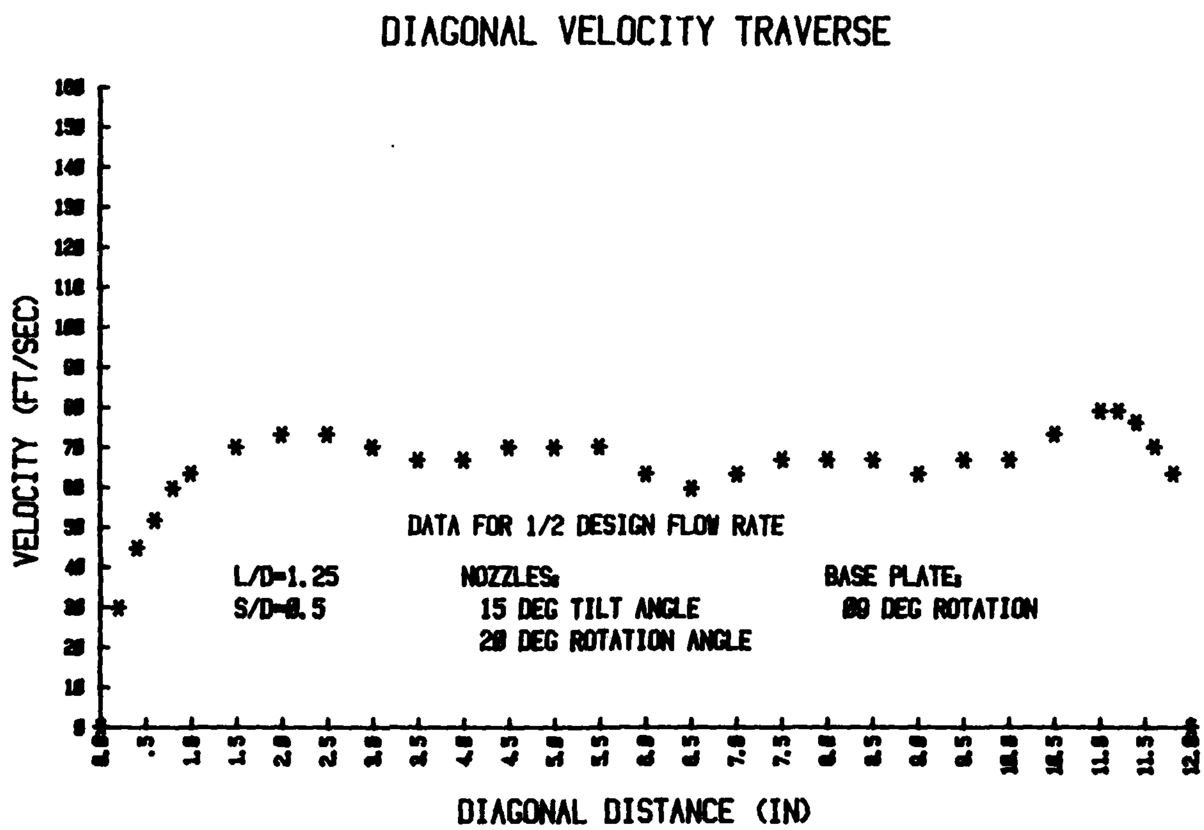



Figure 26. VTD

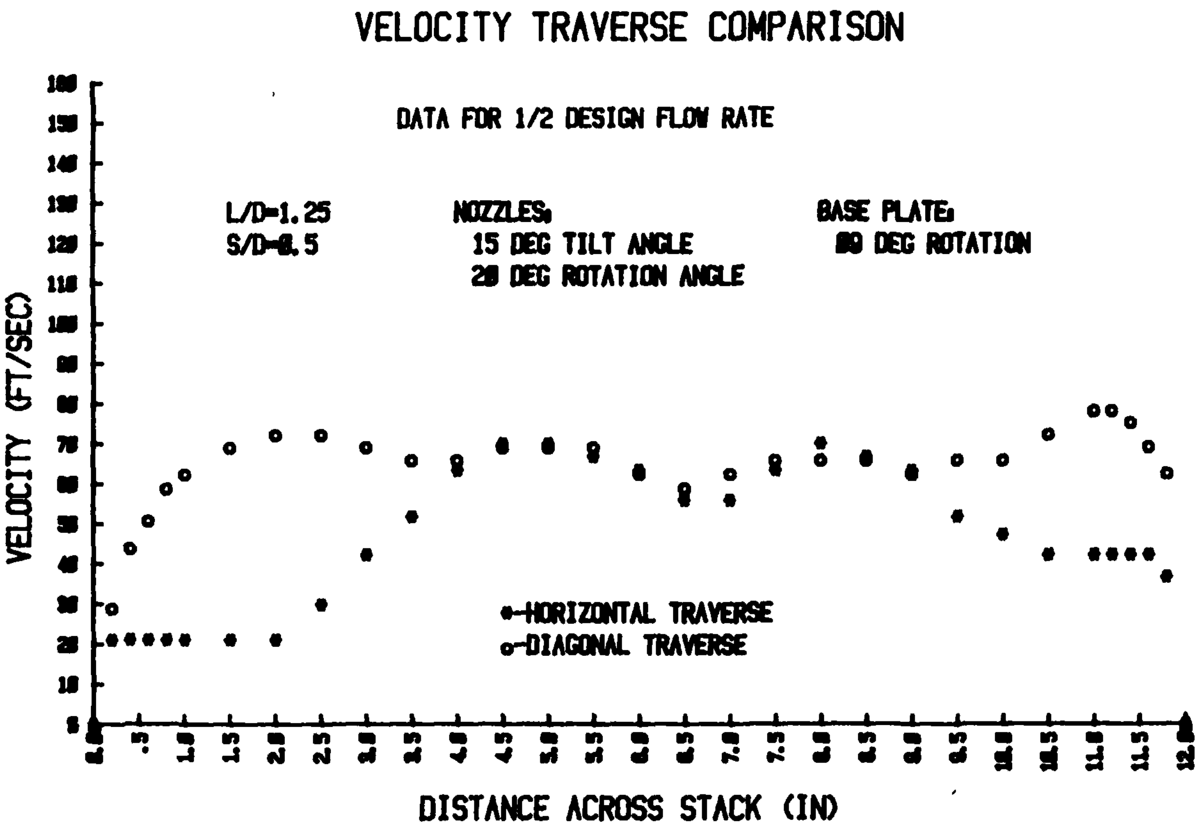



Figure 26. VTD

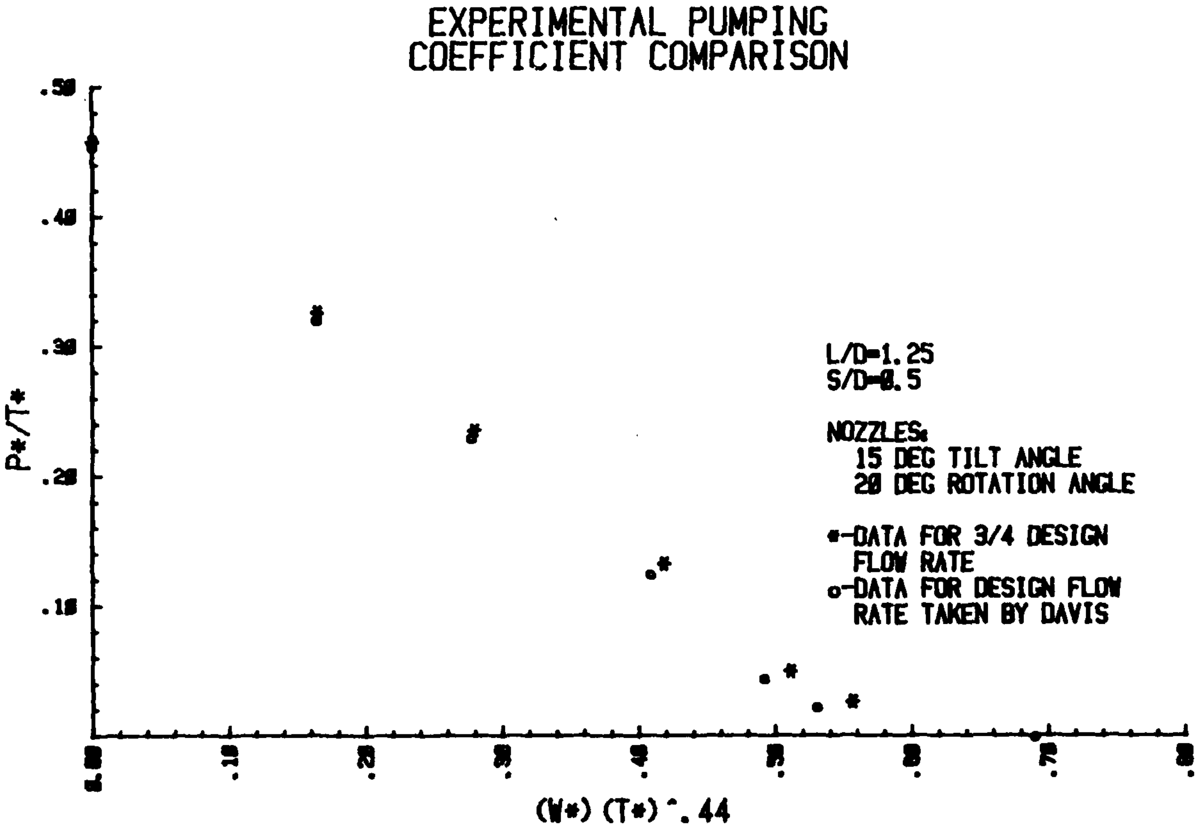



Figure 27. 75 Percent Design Flow

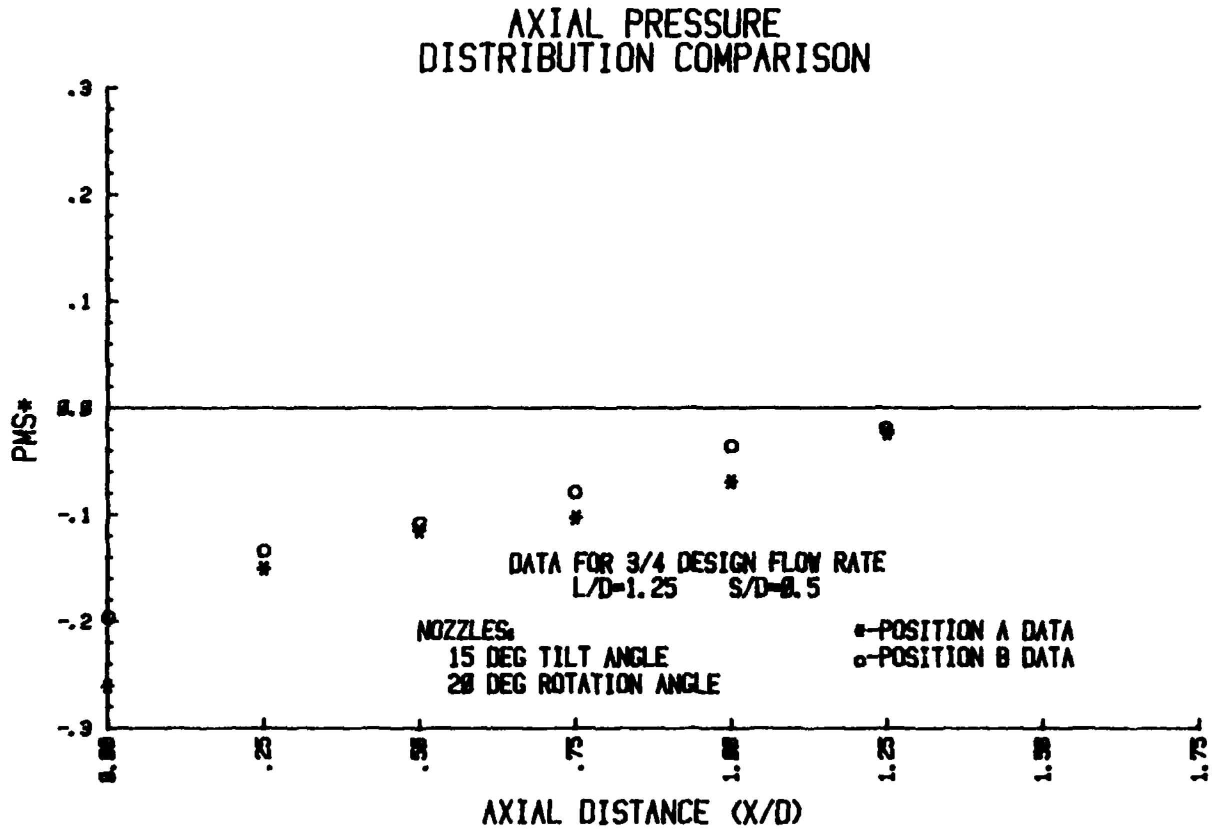



Figure 27. MSD

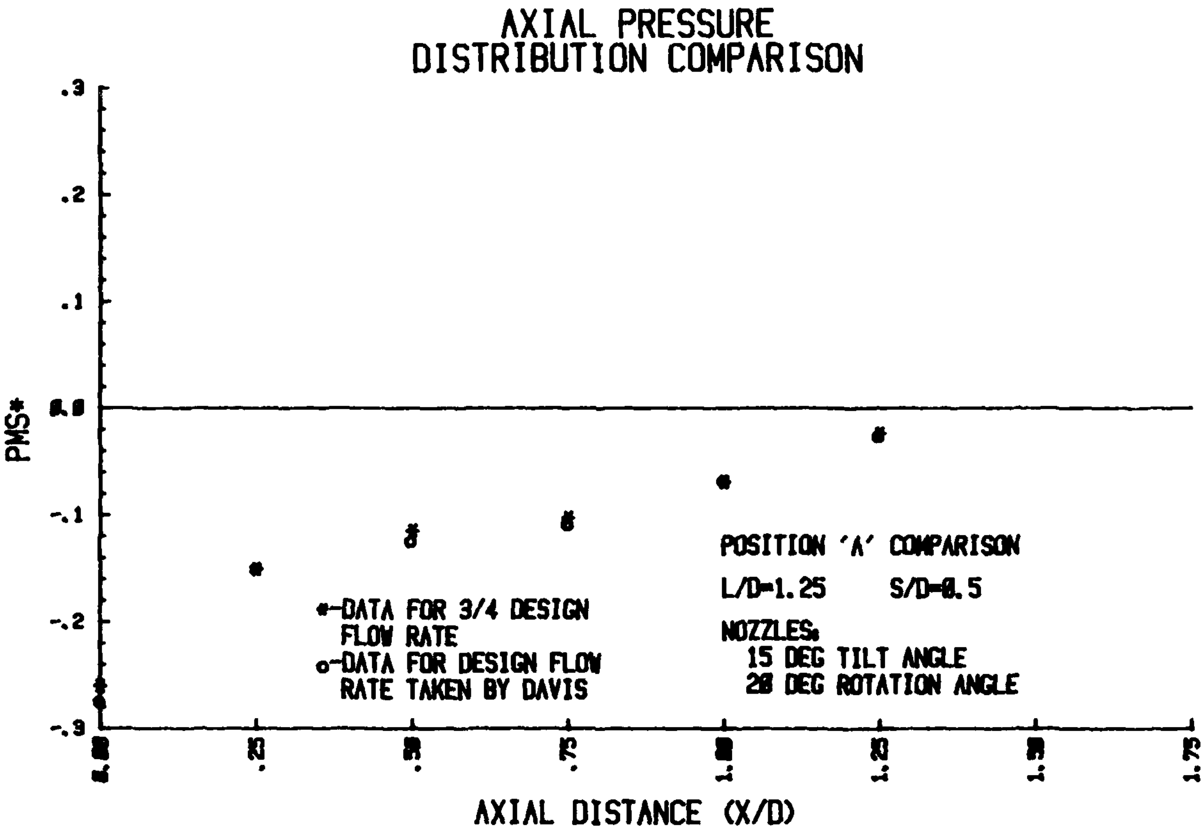



Figure 27. MSD

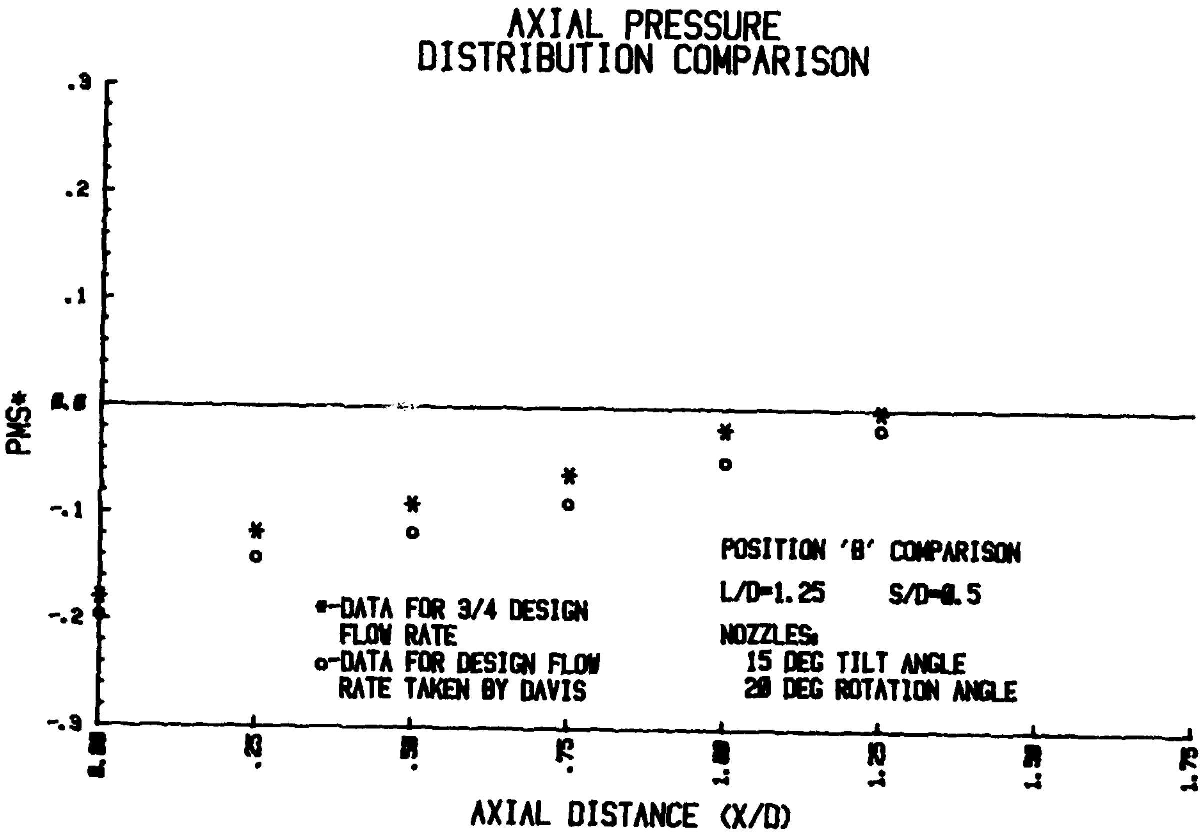



Figure 27. MSD

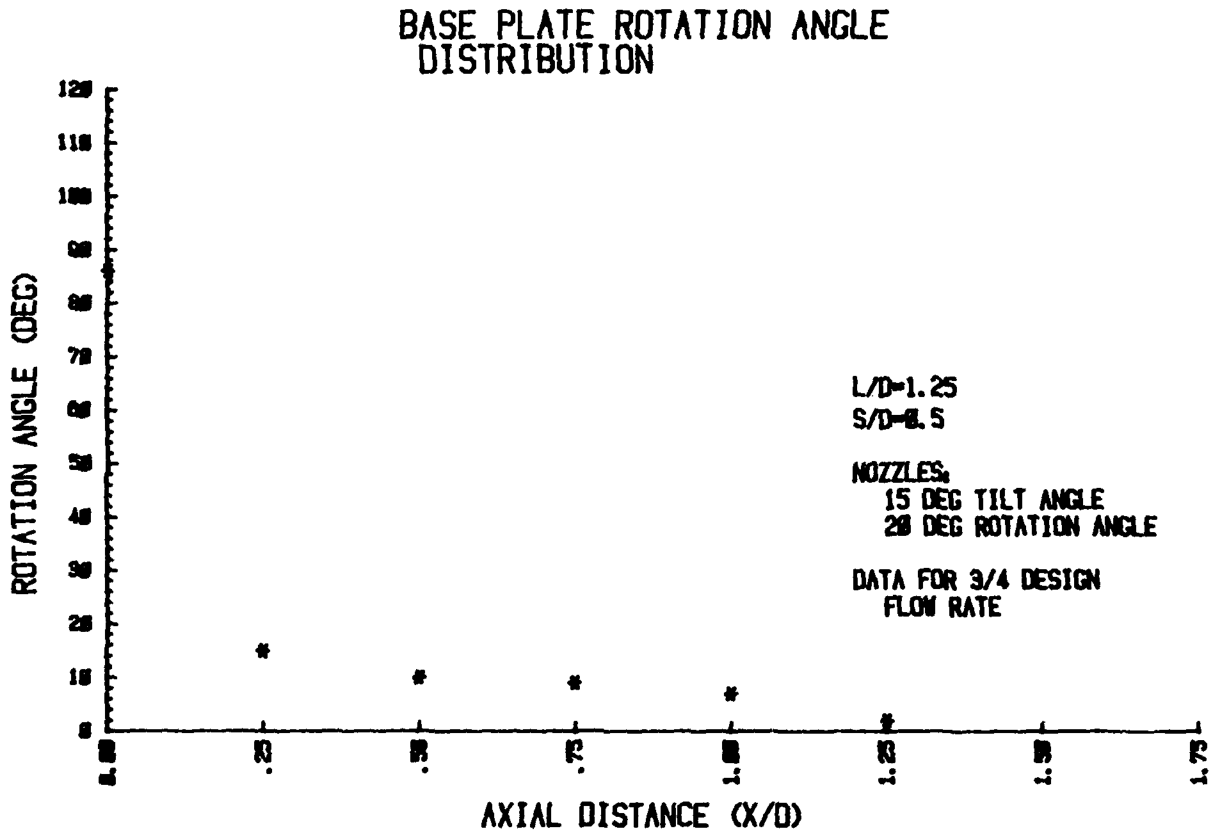



Figure 27. MSD

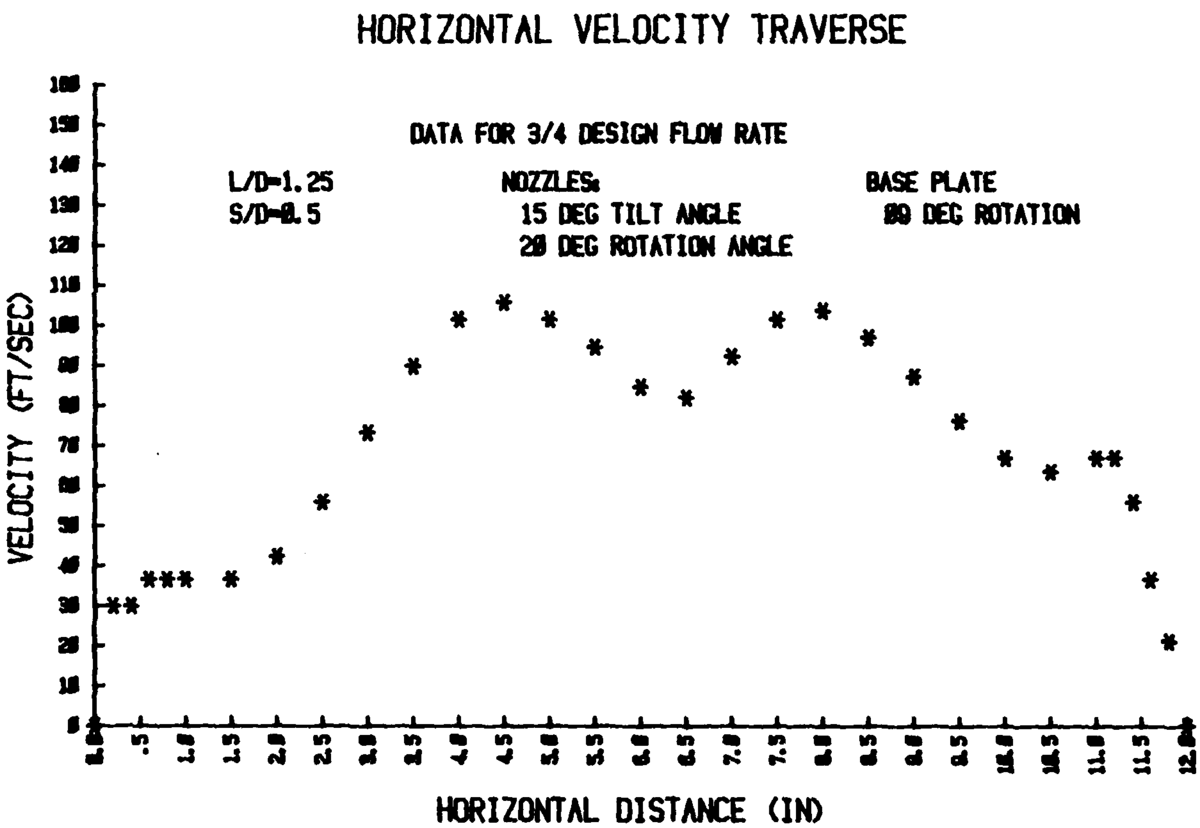



Figure 27. VTD

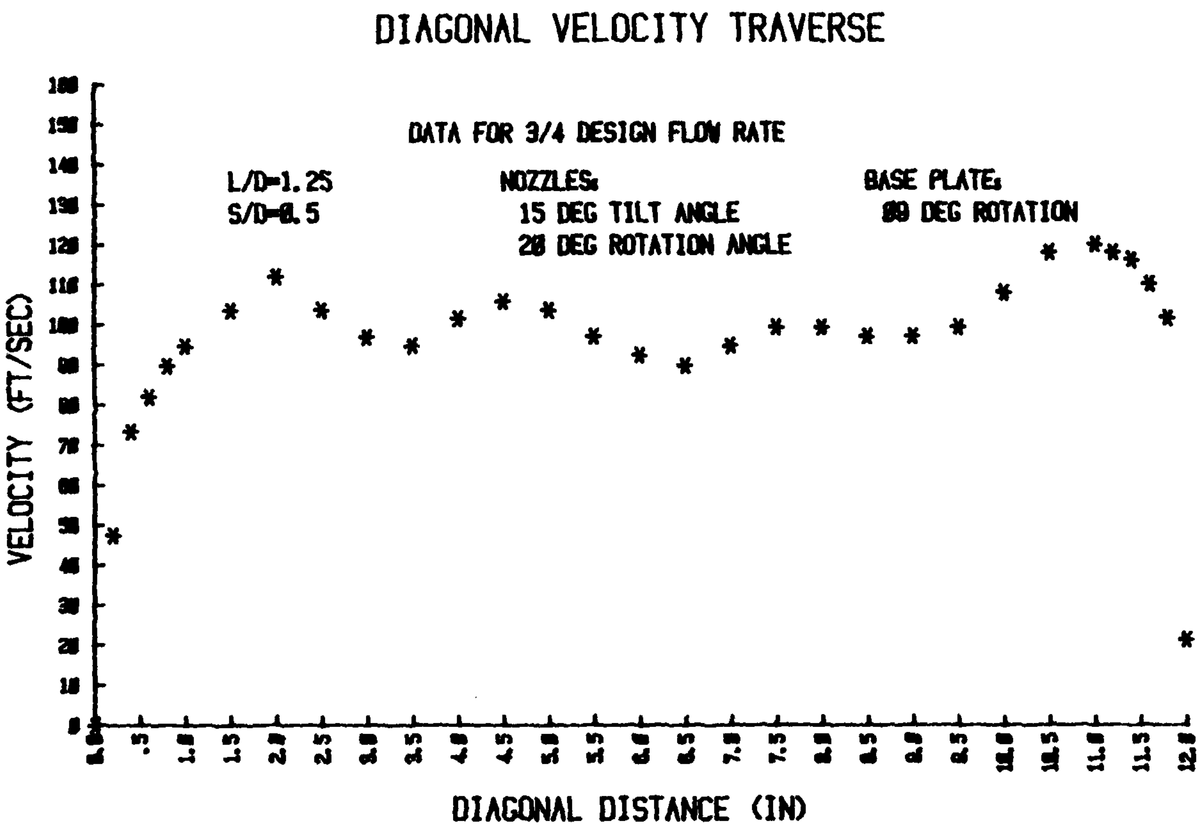


Figure 27. VTD

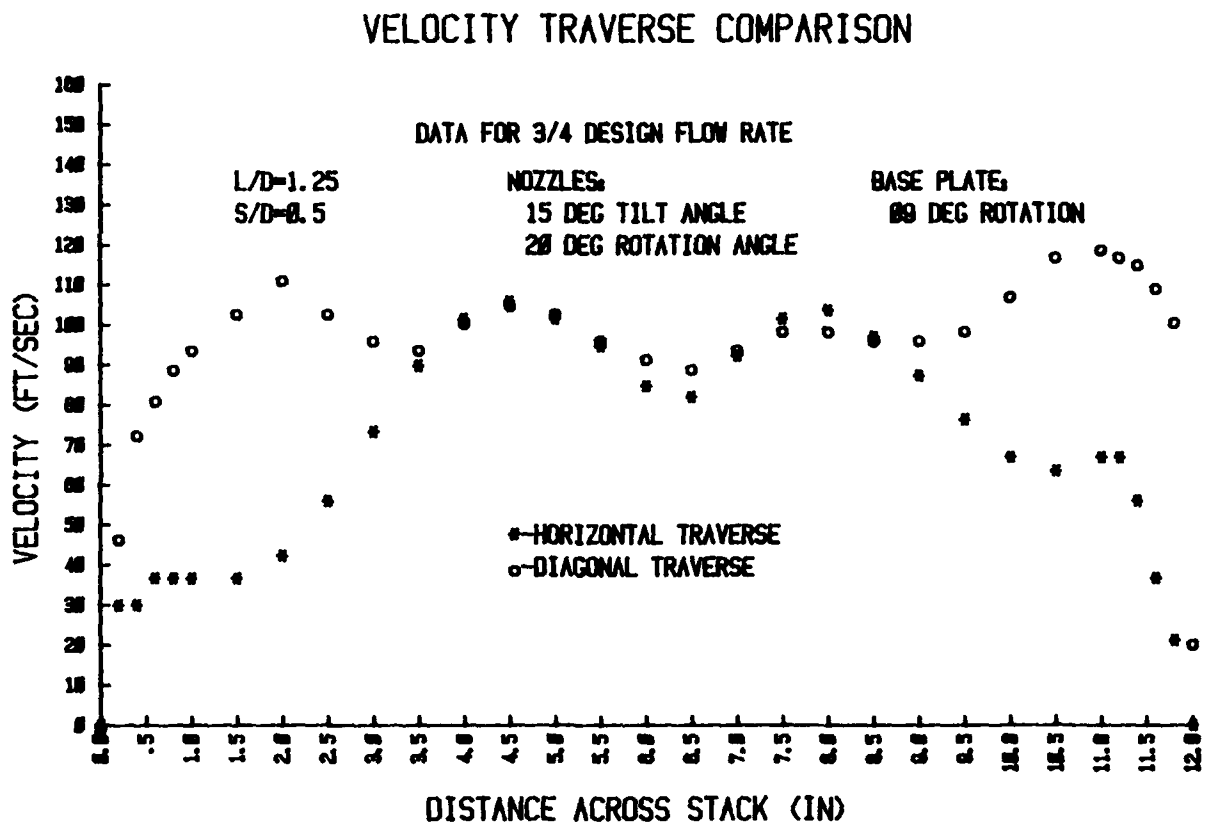



Figure 27. VTD

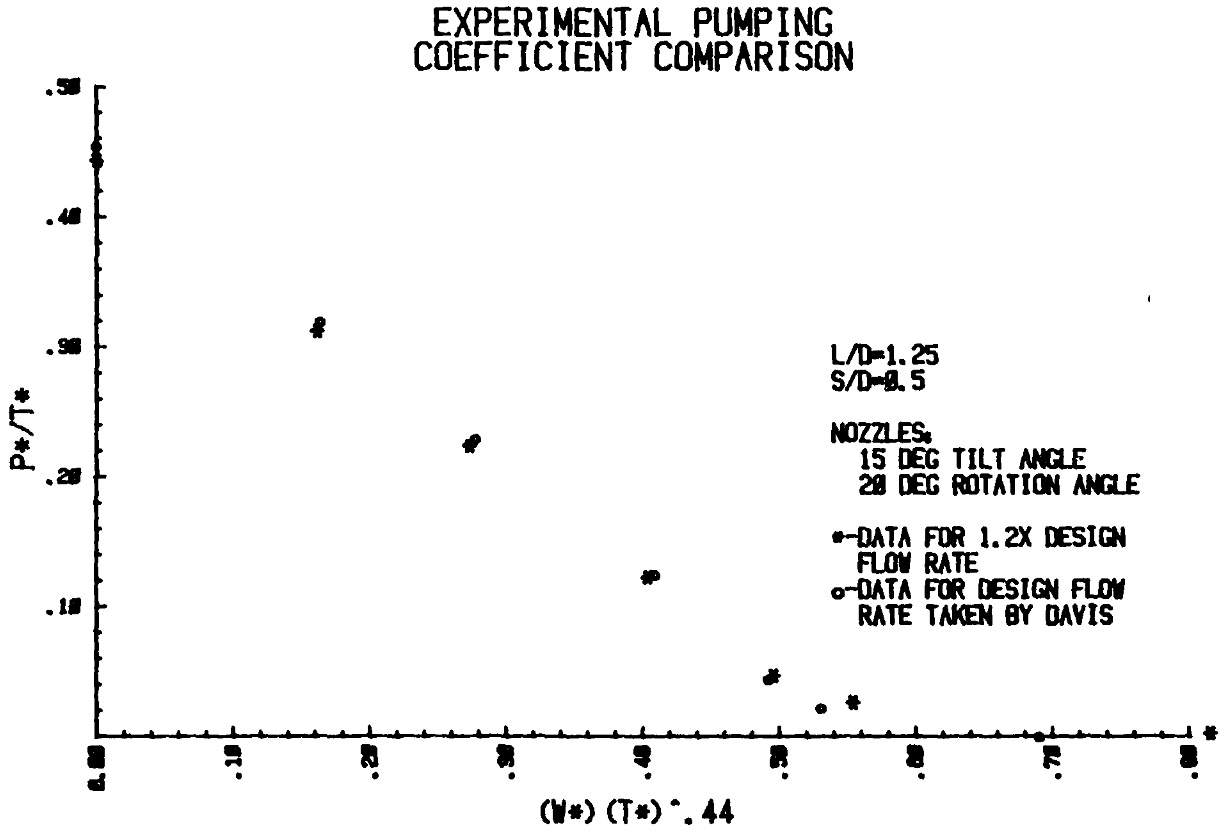



Figure 28. 120 Percent Design Flow

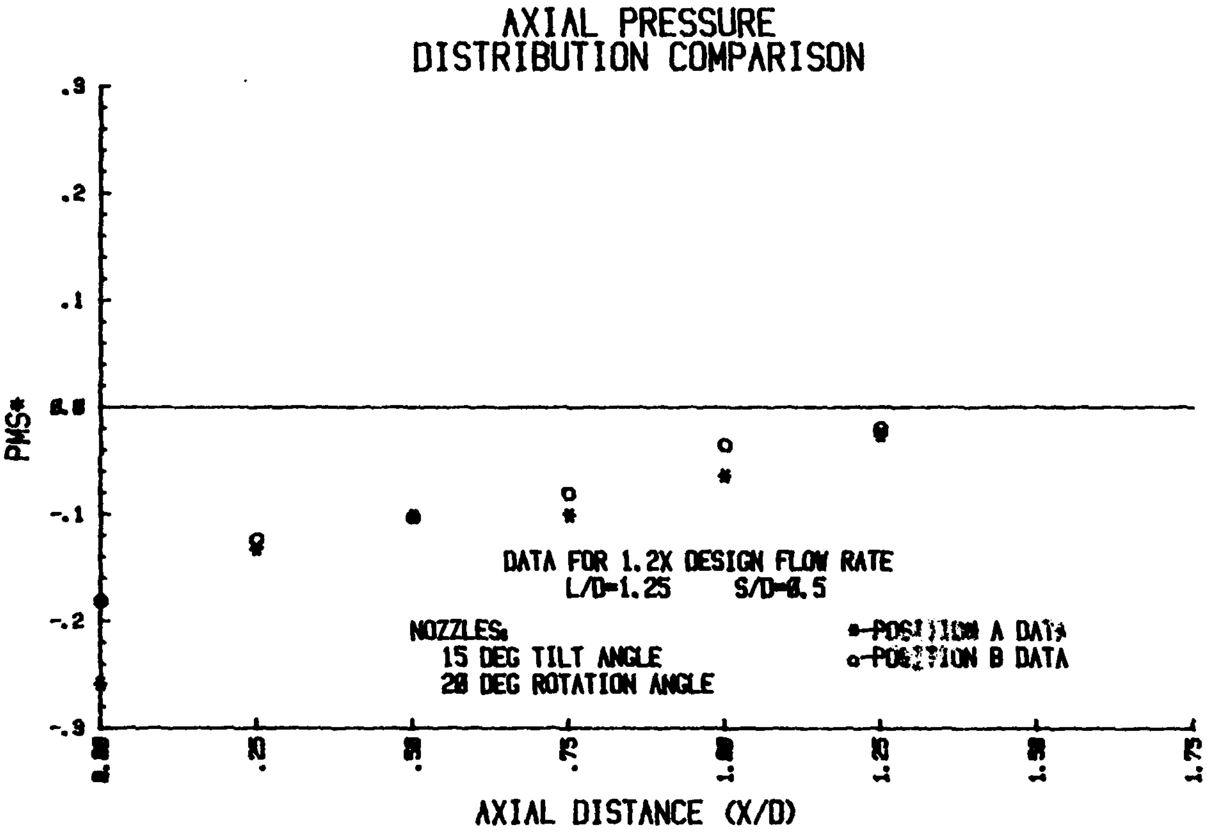



Figure 28. MSD

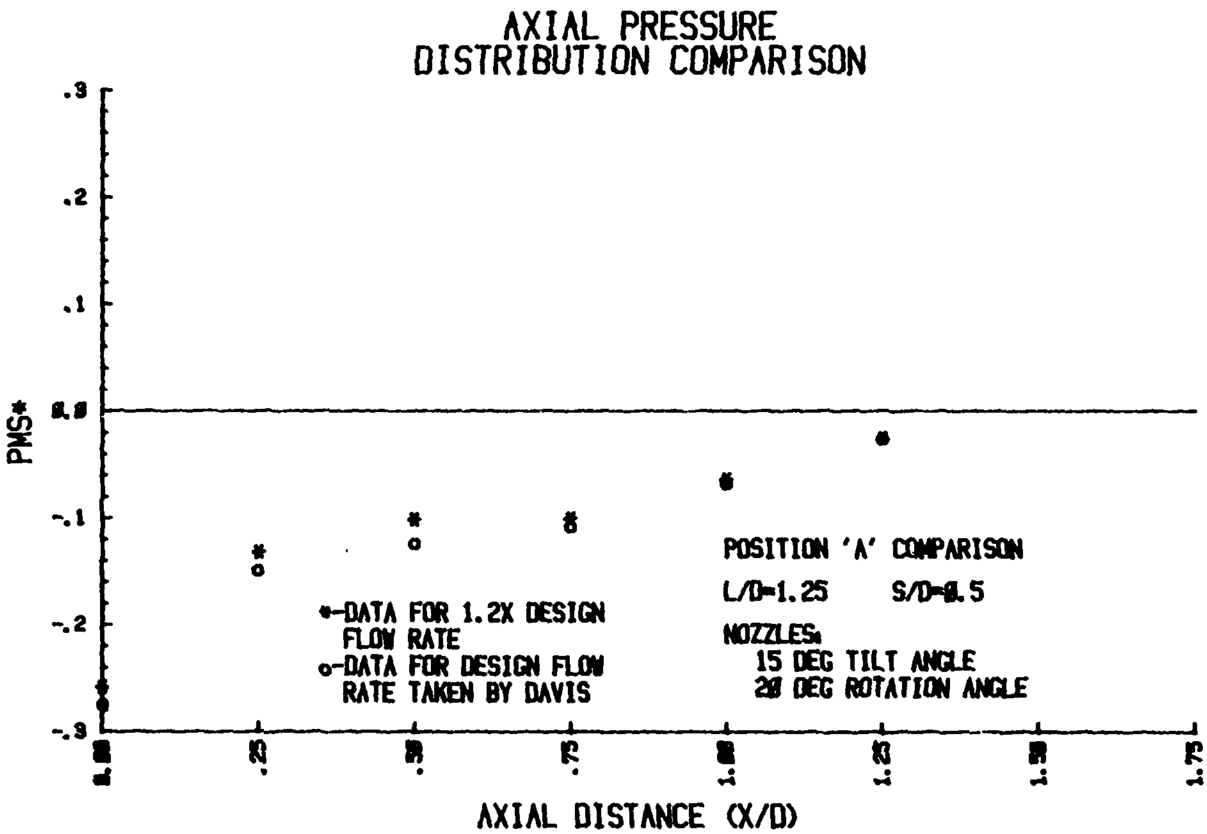



Figure 28. MSD

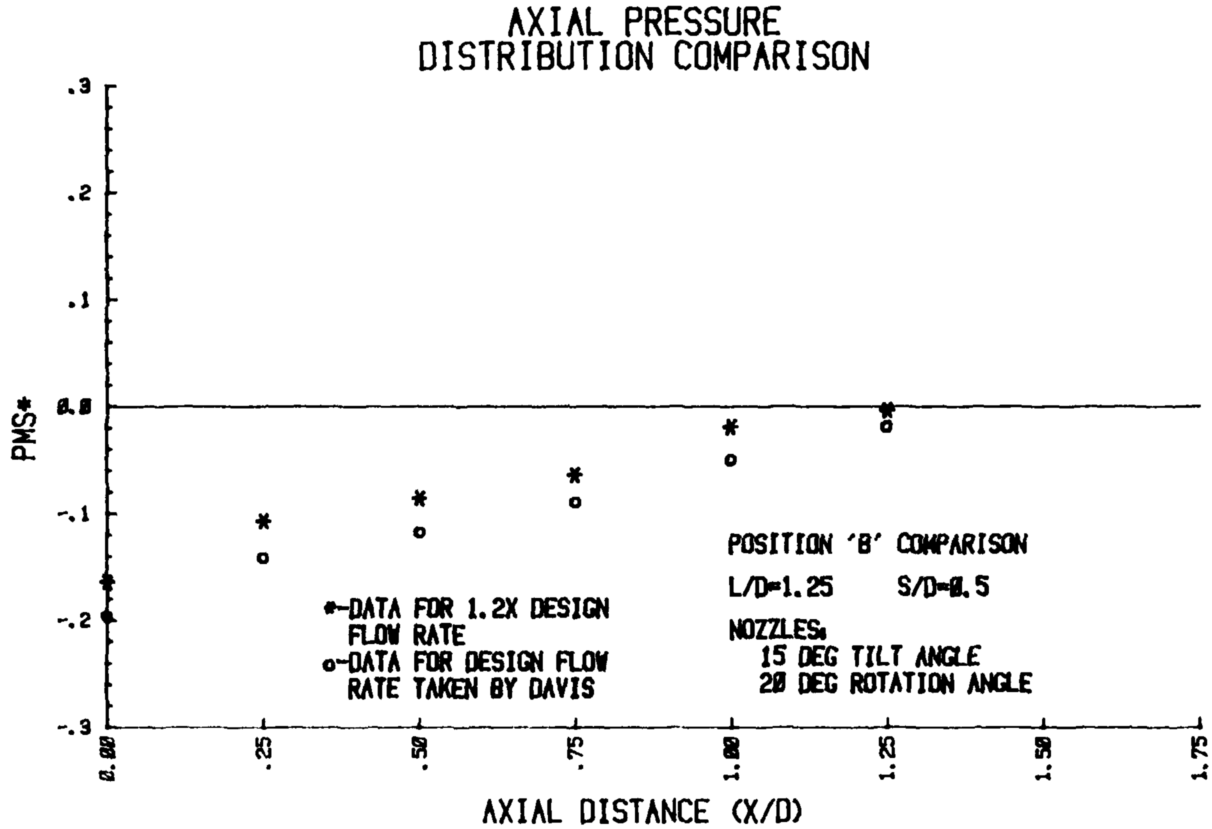



Figure 28. MSD

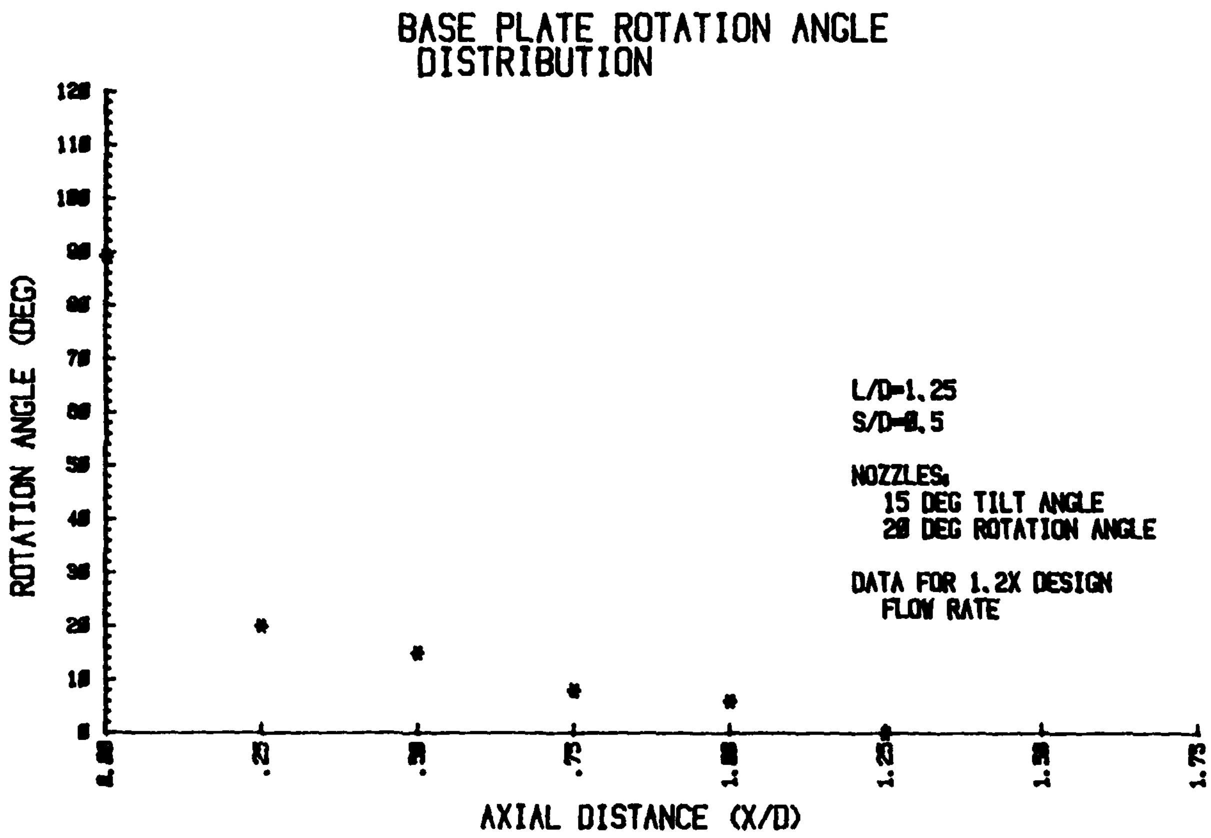



Figure 28. MSD

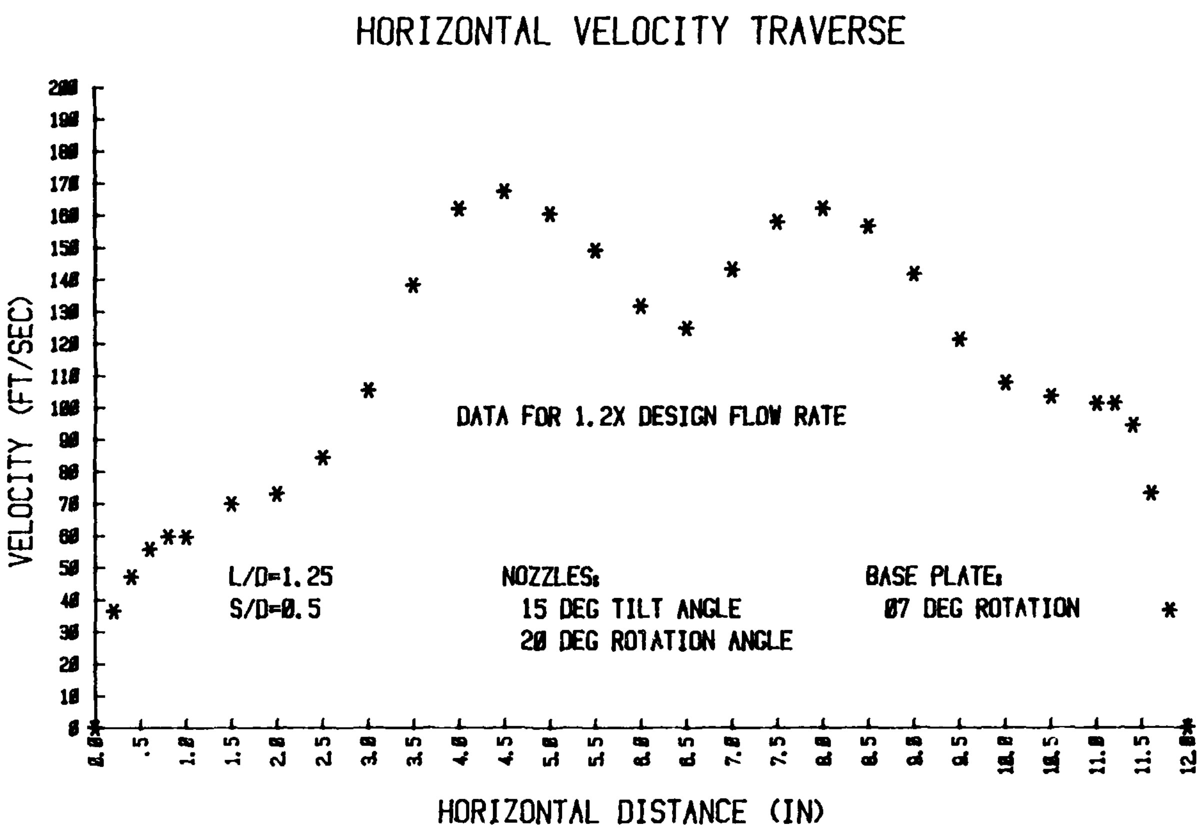



Figure 28. VTD

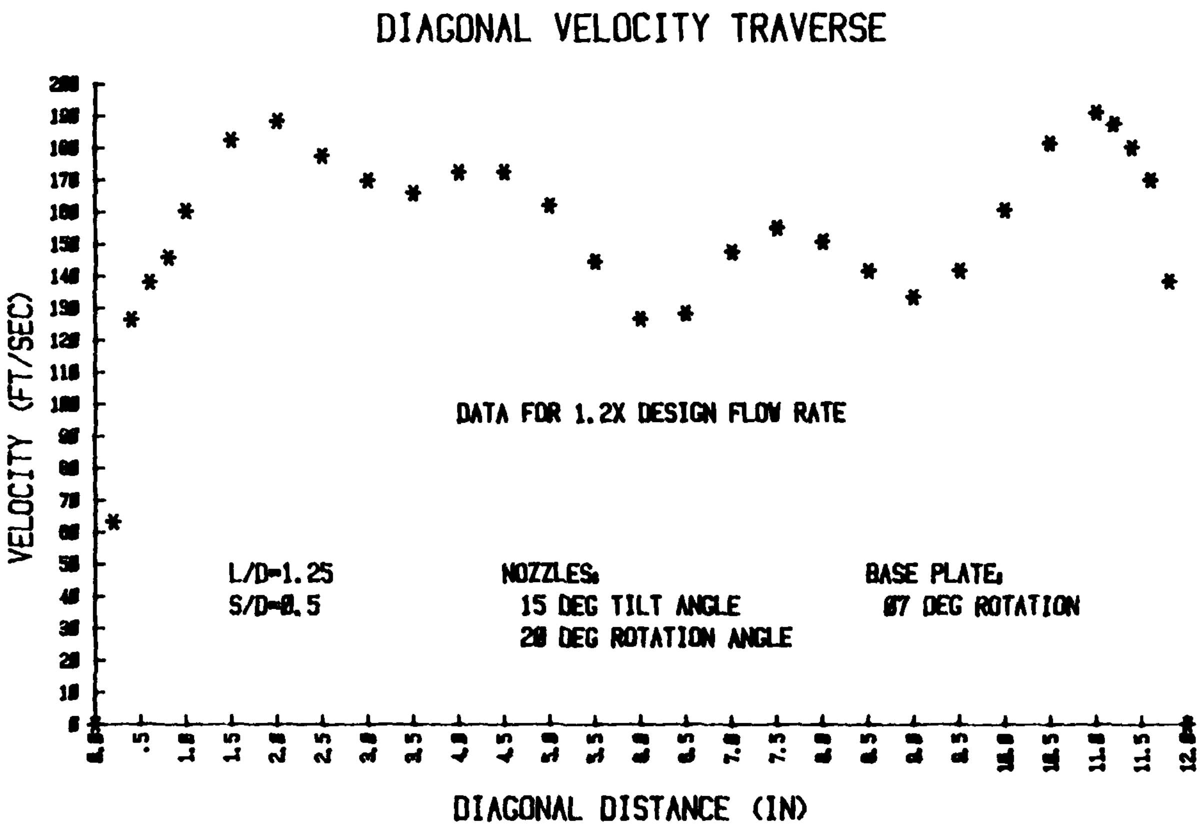



Figure 28. VTD

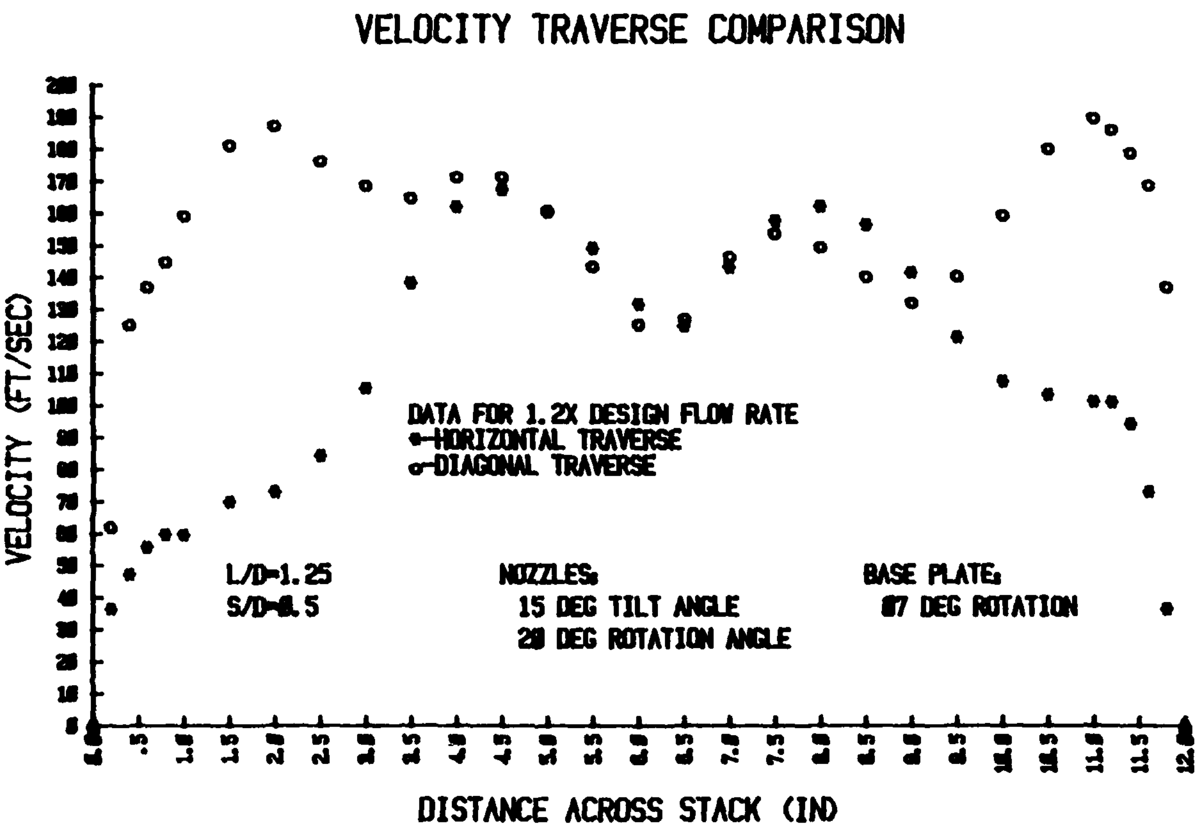



Figure 28. VTD

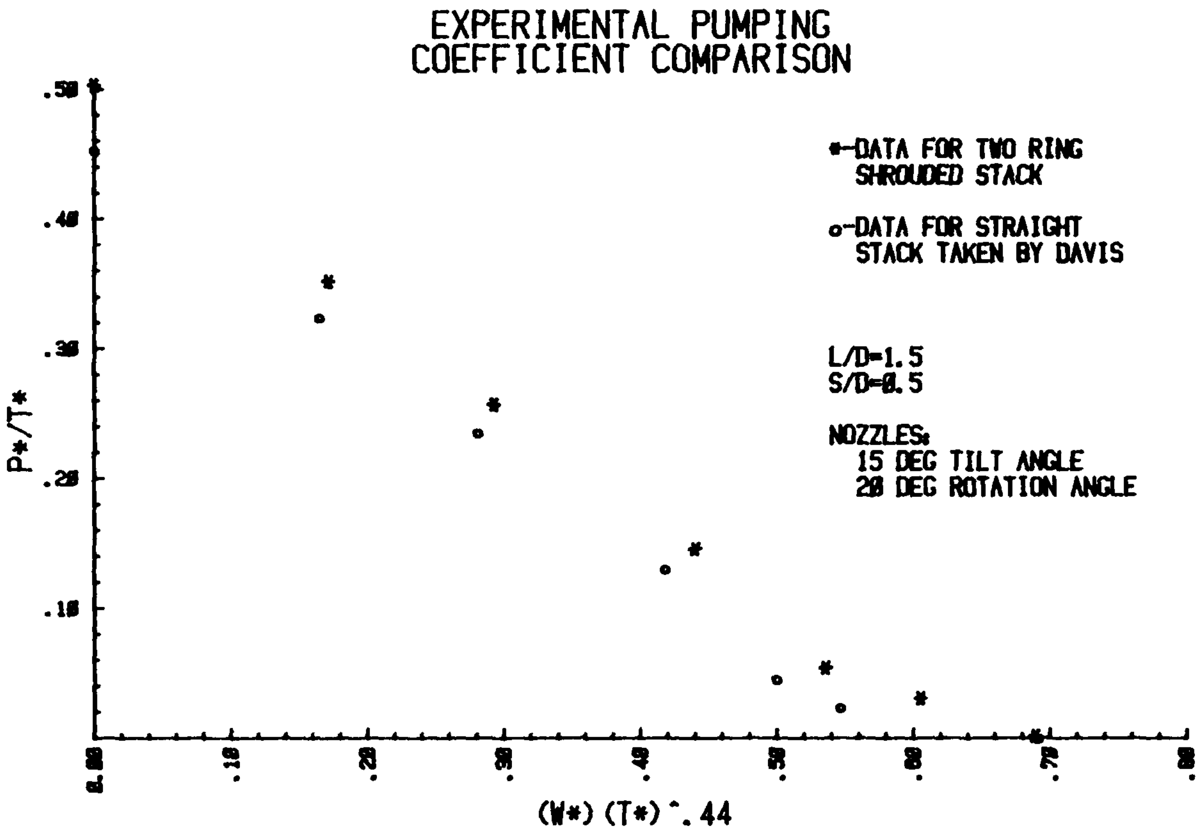



Figure 29. Slots Closed

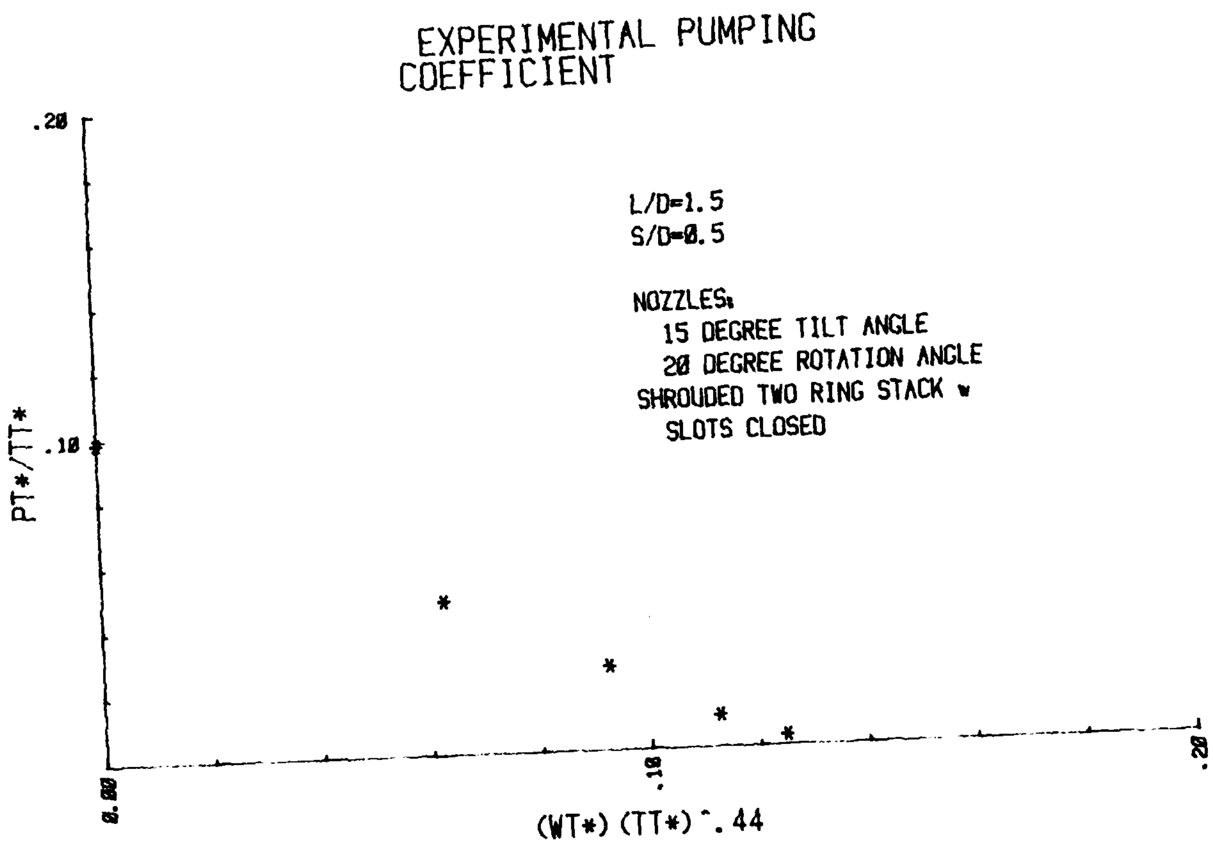



Figure 29. PCD (Tertiary)

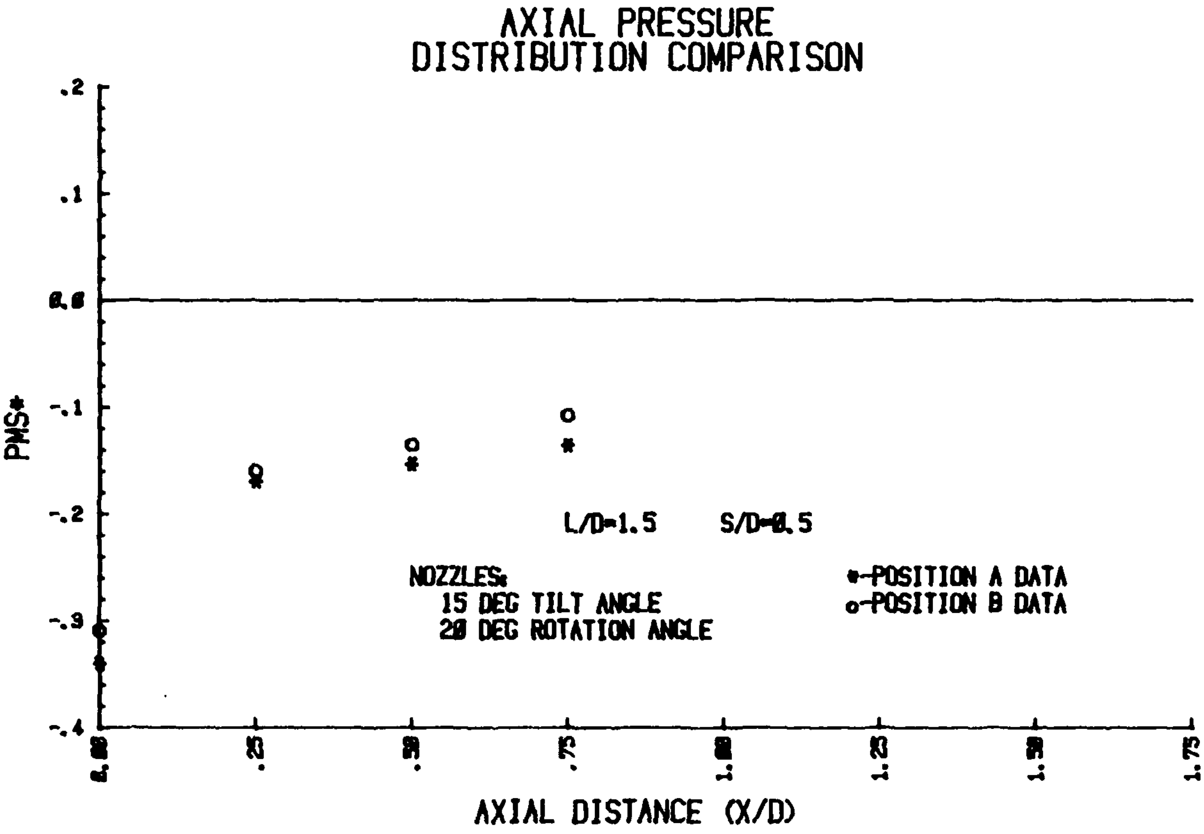



Figure 29. MSD

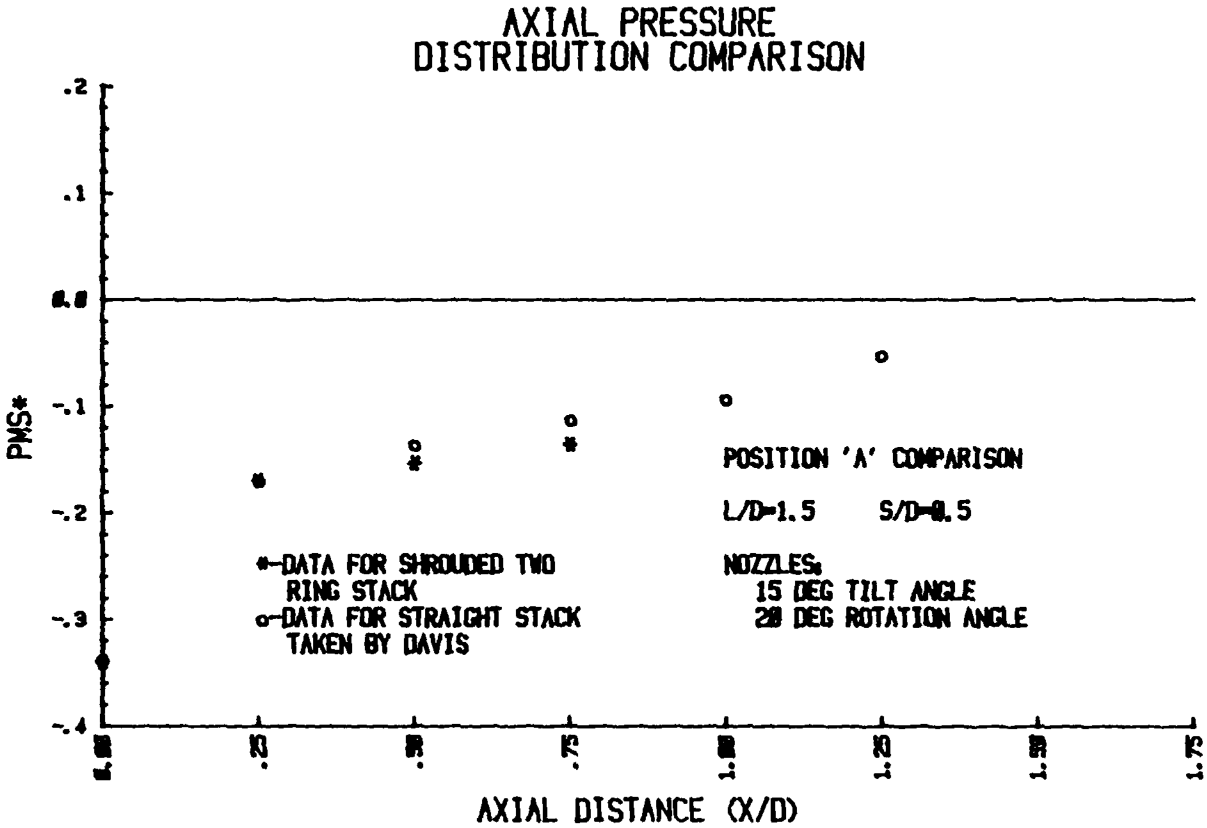



Figure 29. MSD

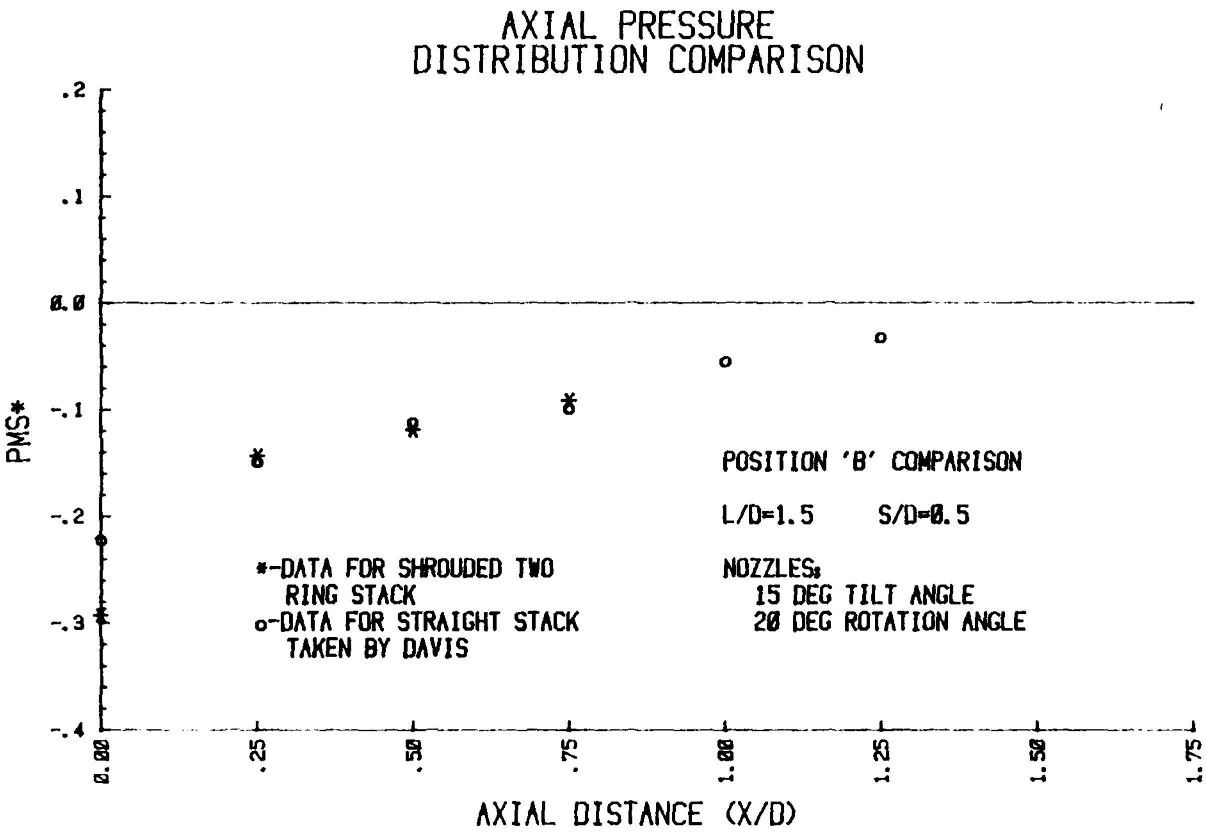



Figure 29. MSD

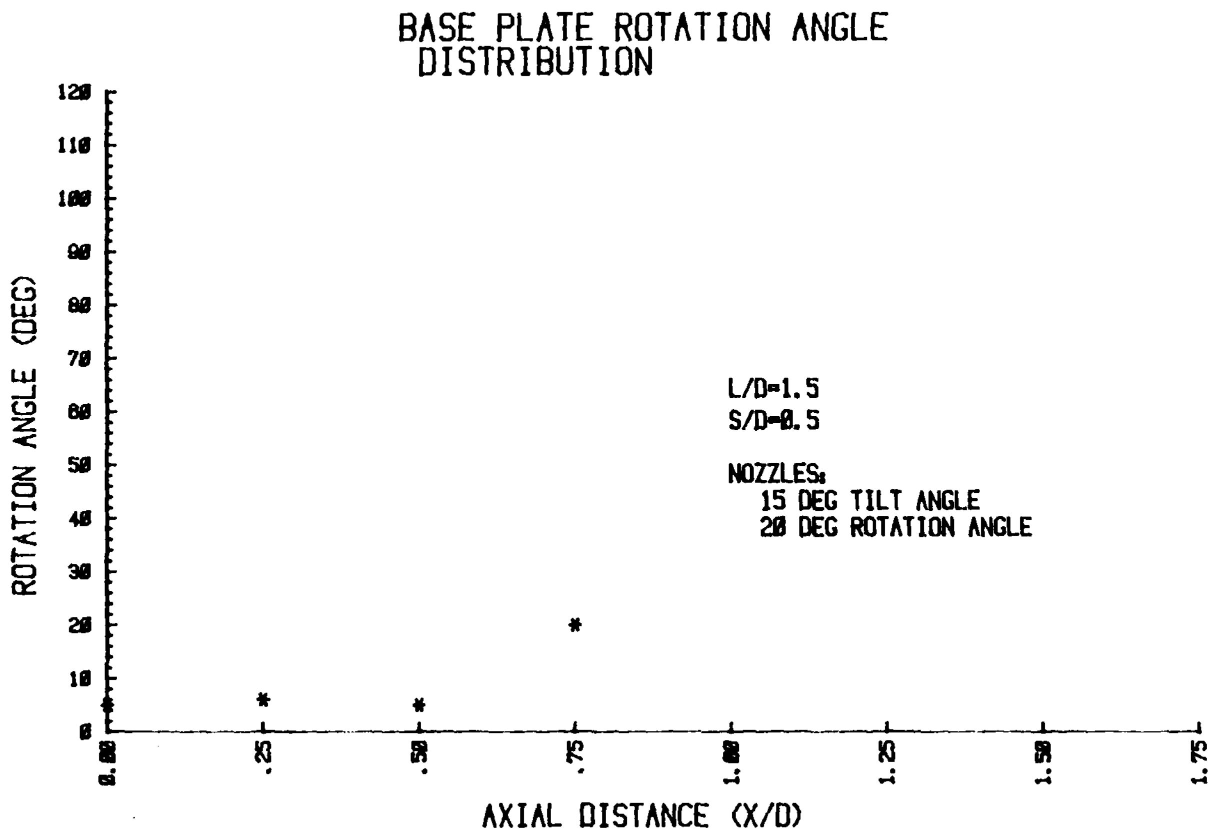



Figure 29. MSD

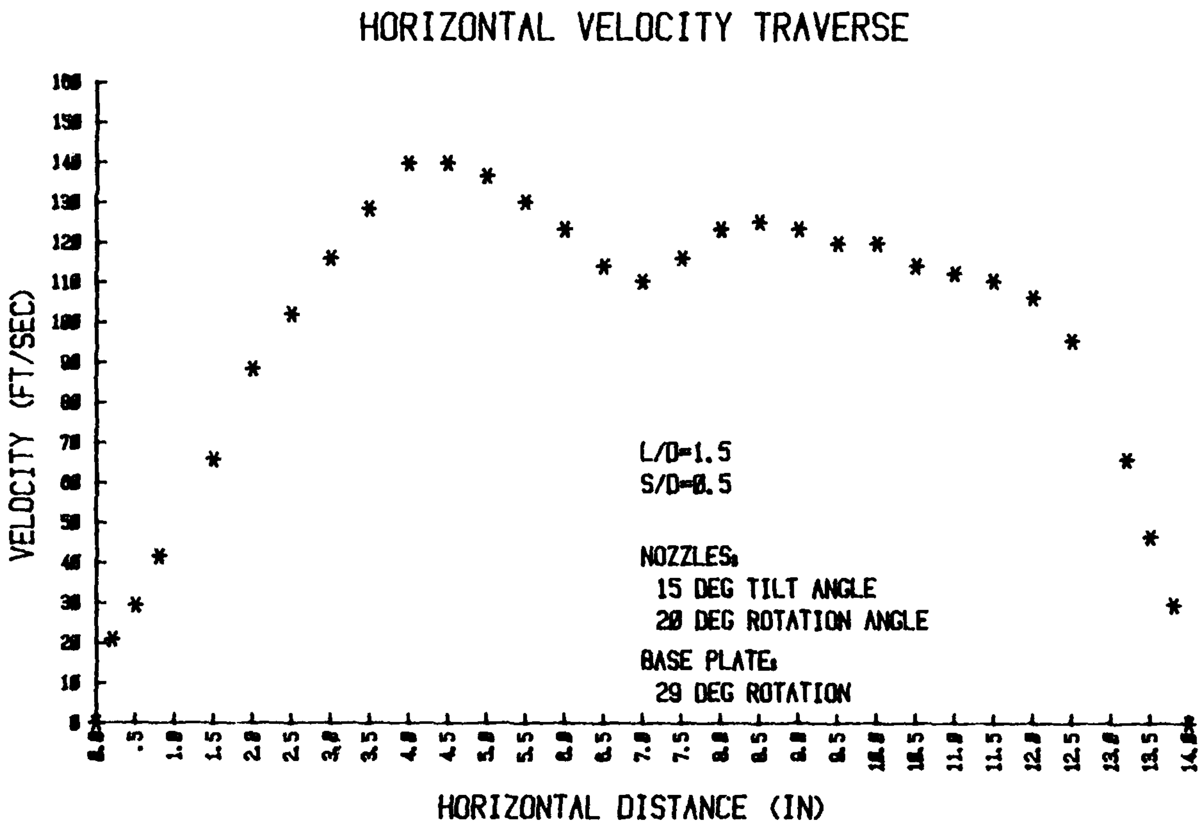



Figure 29. VTD

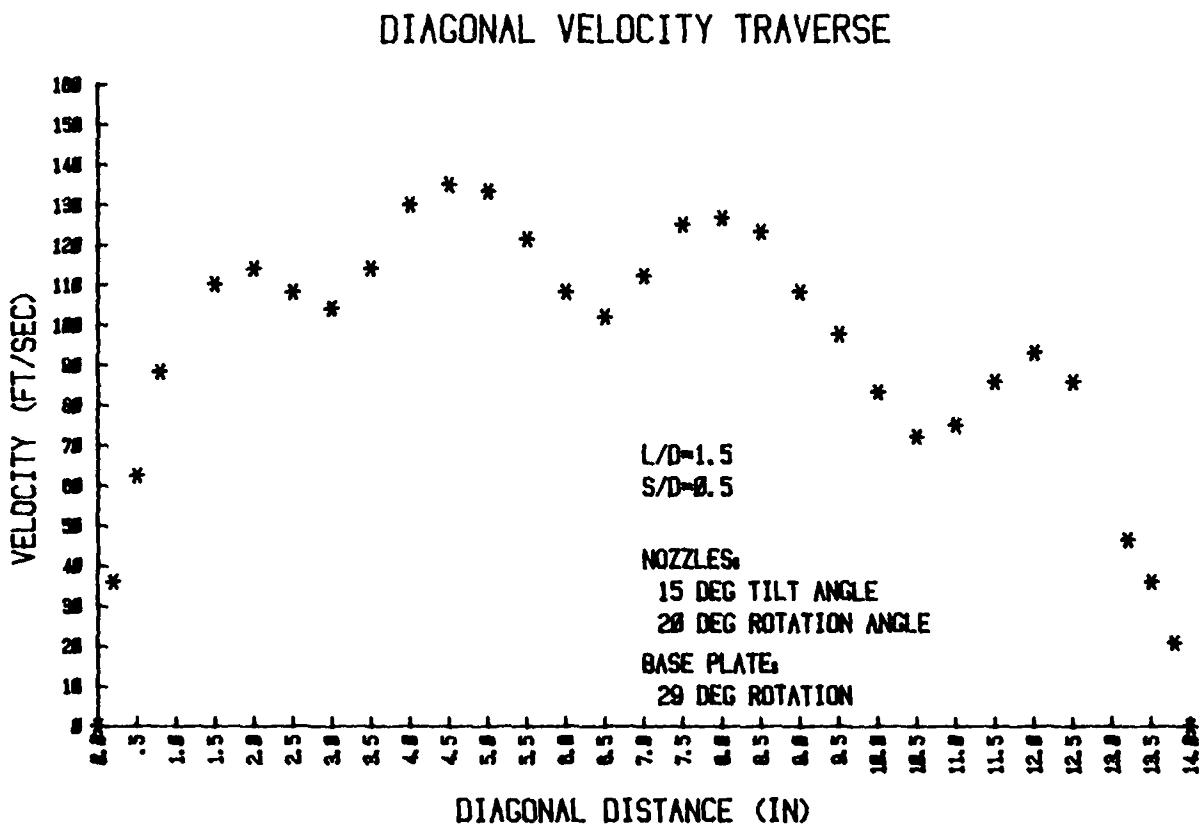



Figure 29. VTD

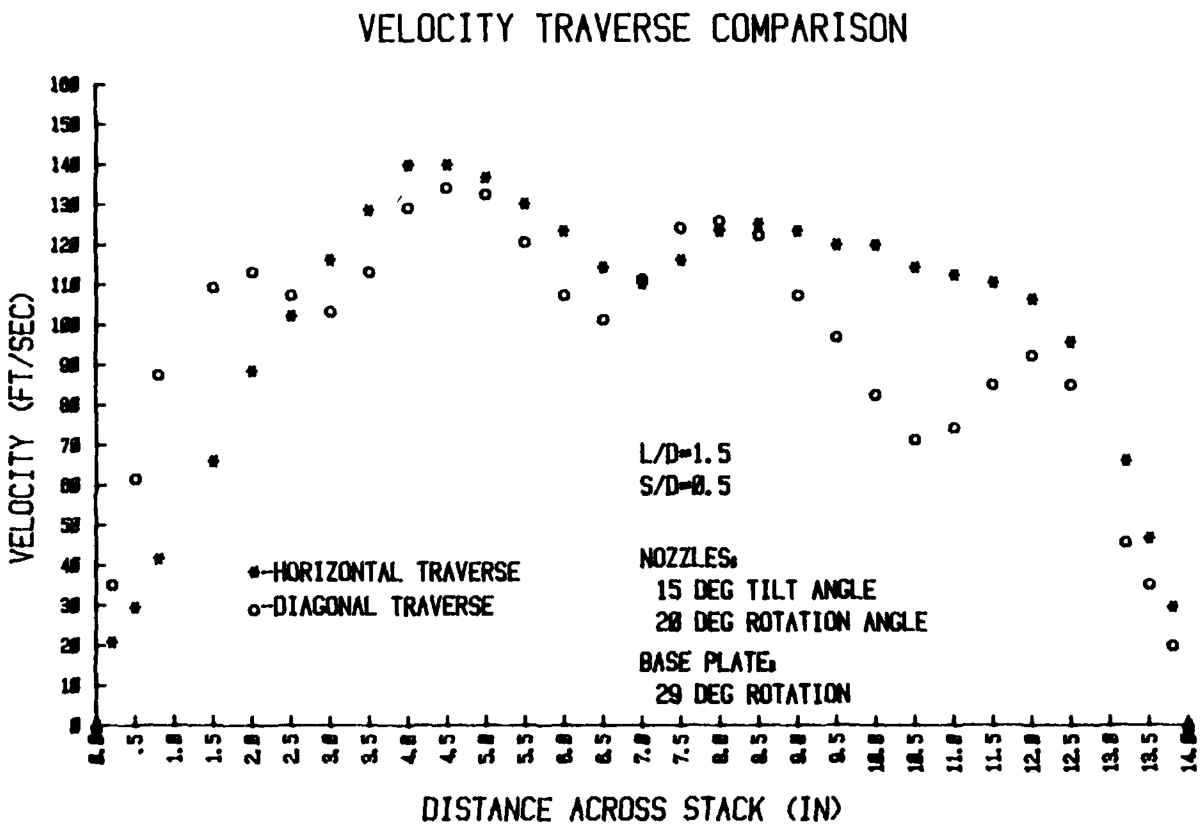



Figure 29. VTD

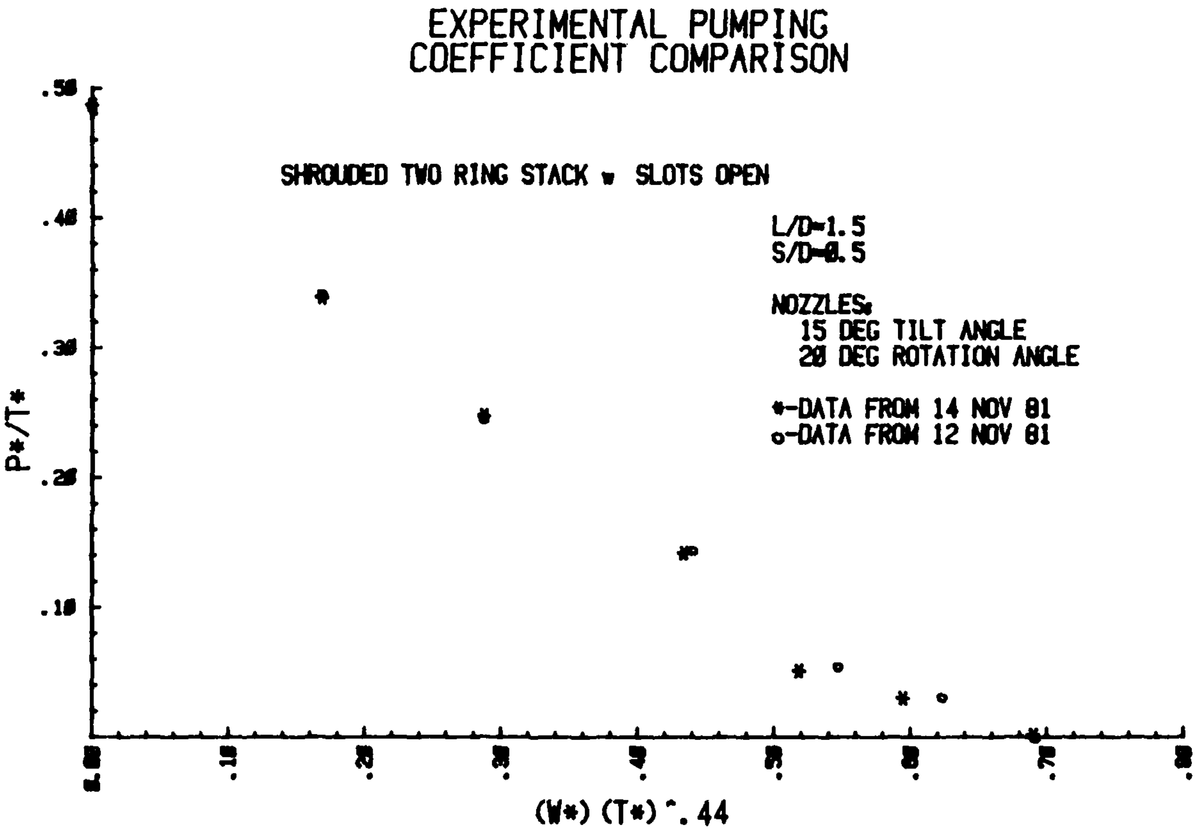



Figure 30. Slots Open

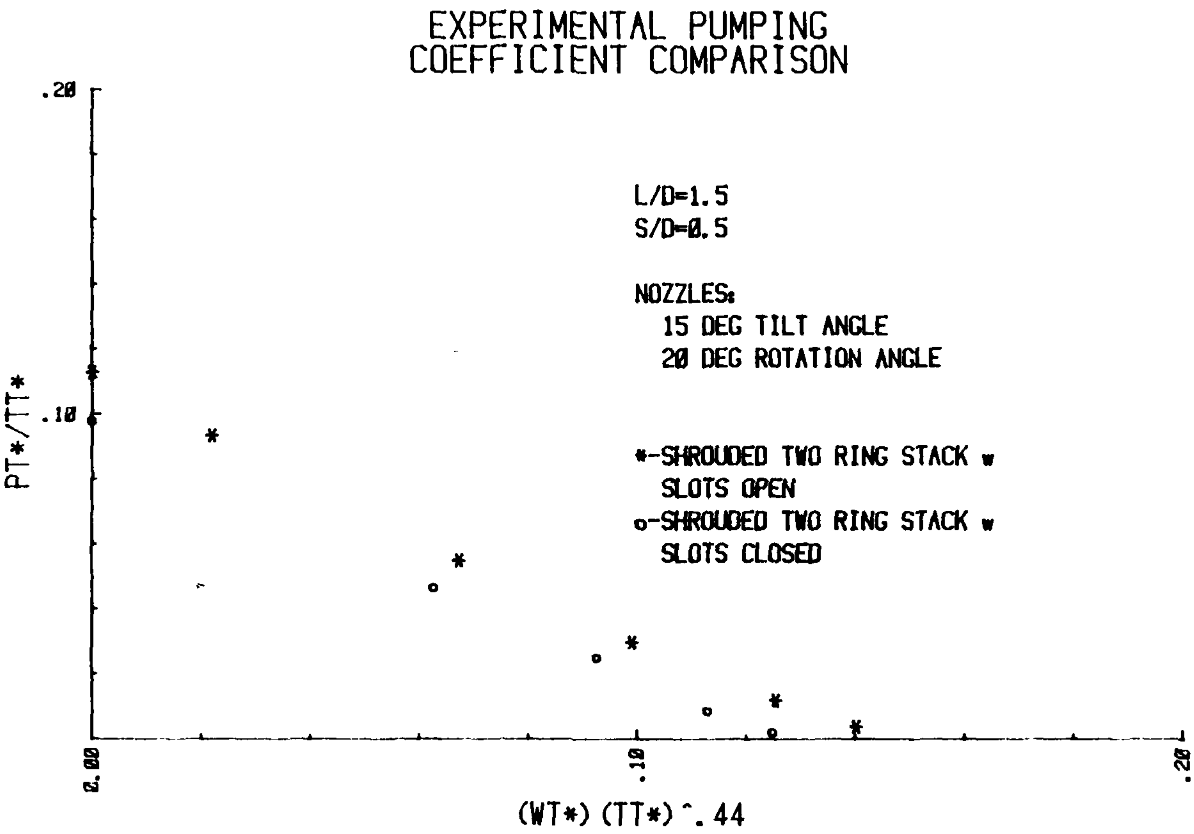



Figure 30. PCD (Tertiary)

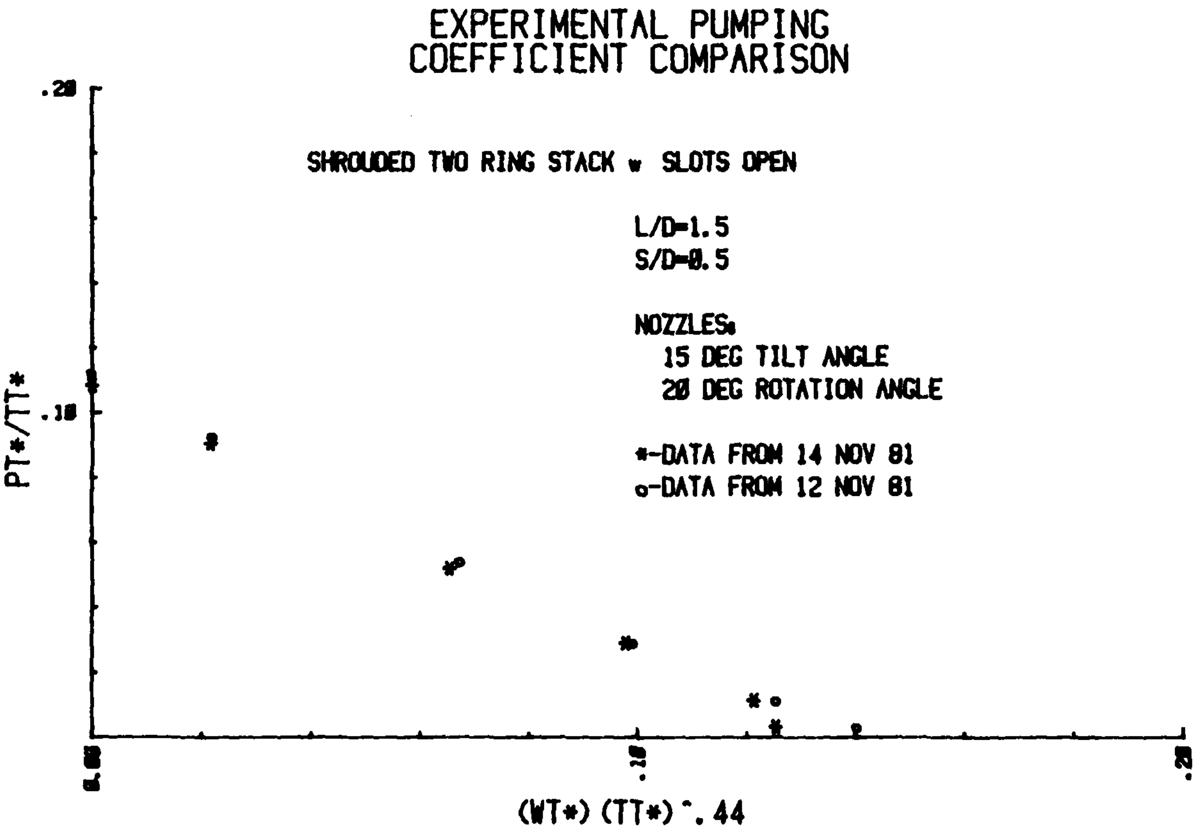



Figure 30. PCD (Tertiary)

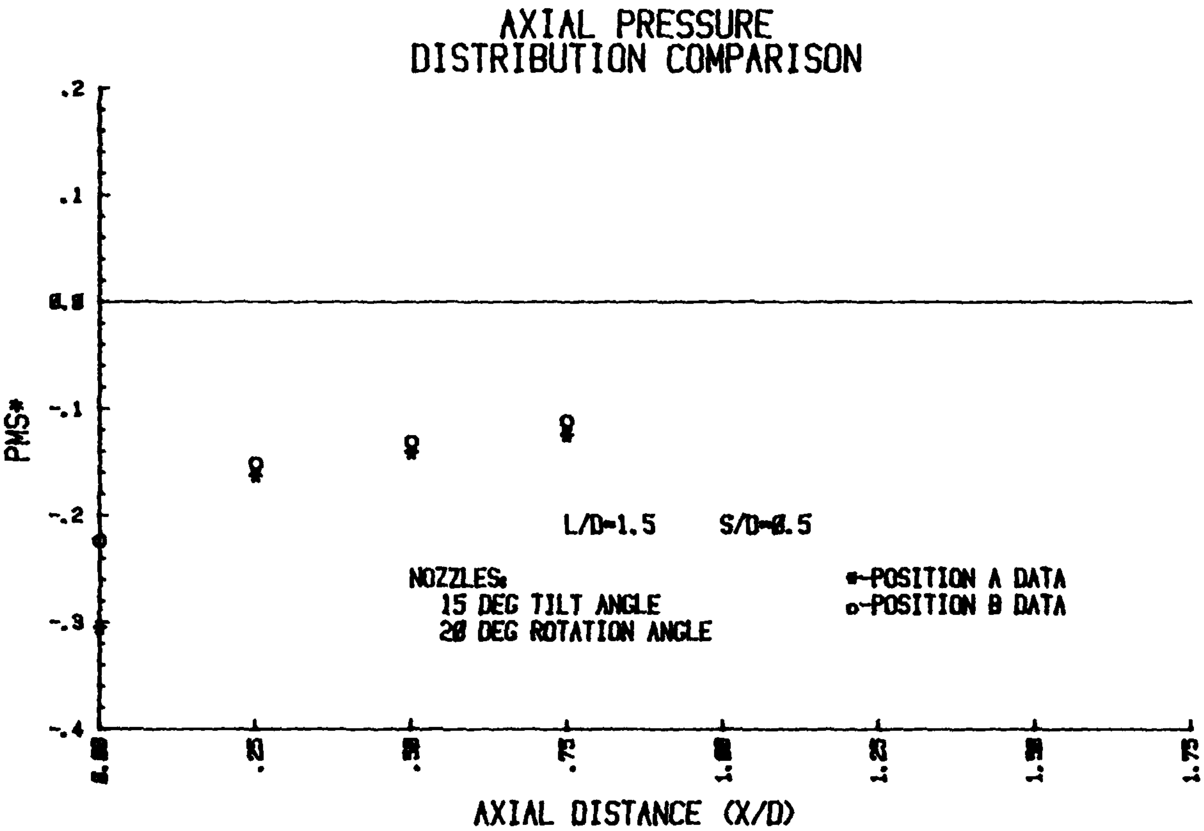



Figure 30. MSD

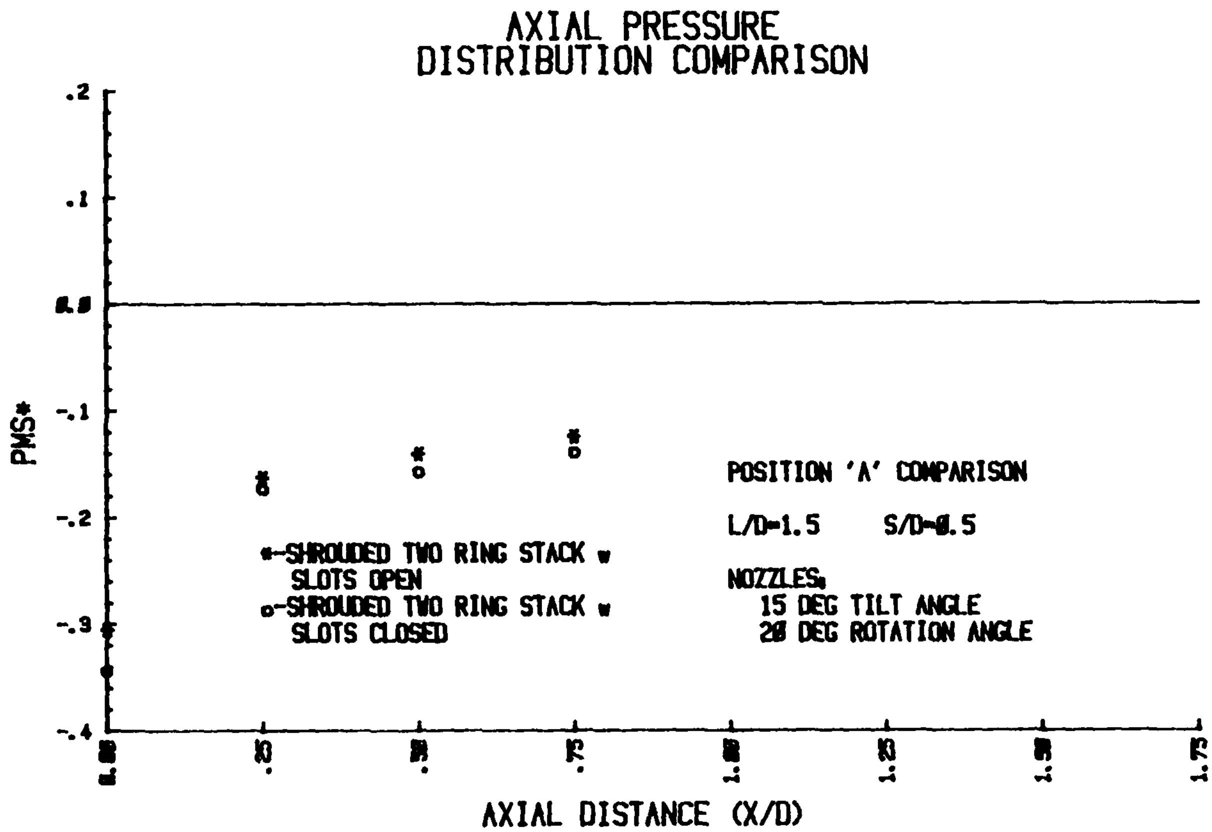



Figure 30. MSD

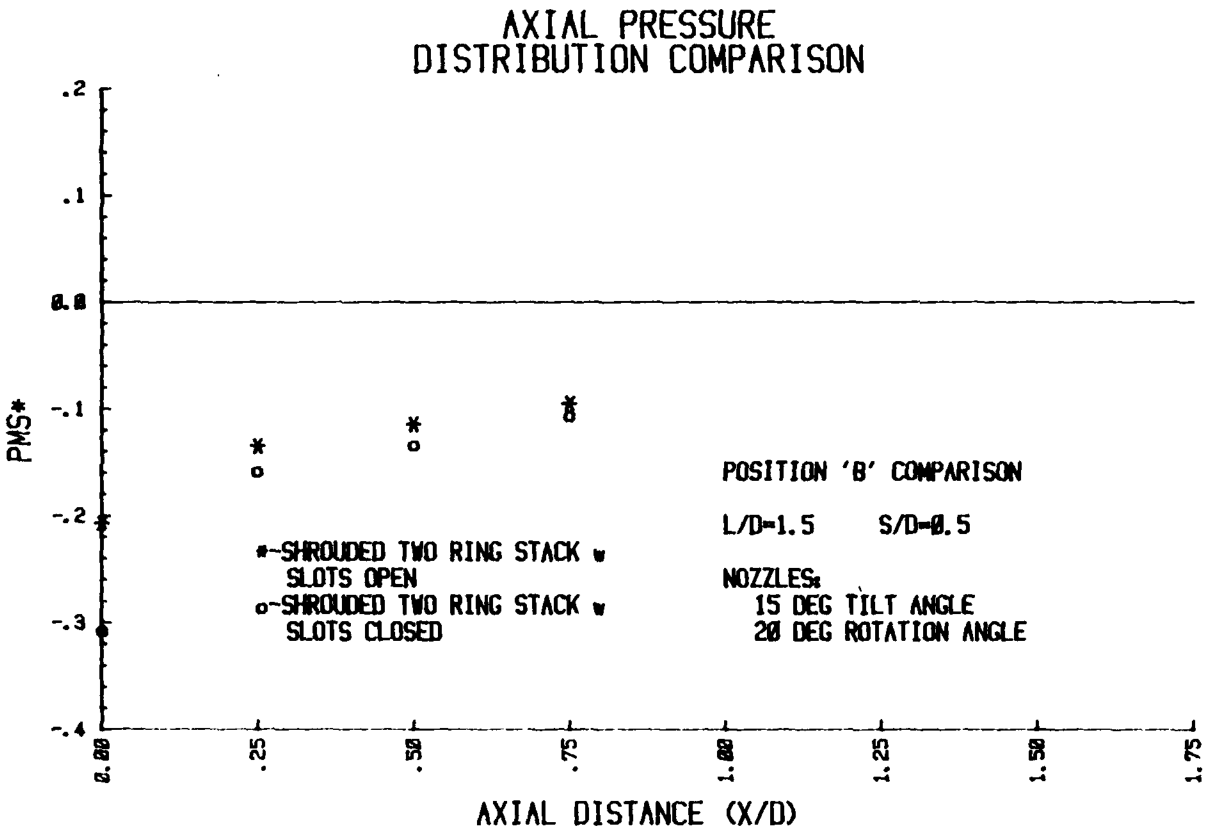



Figure 30. MSD

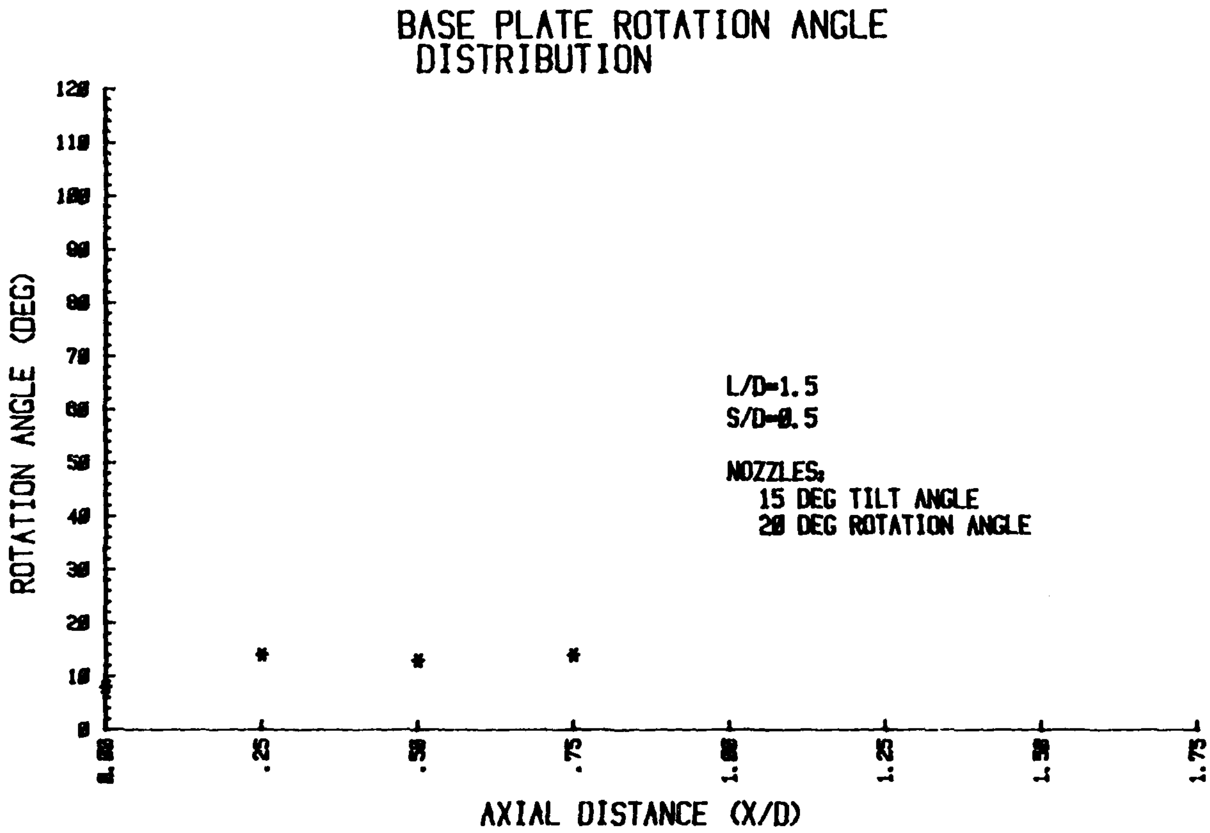



Figure 30. MSD

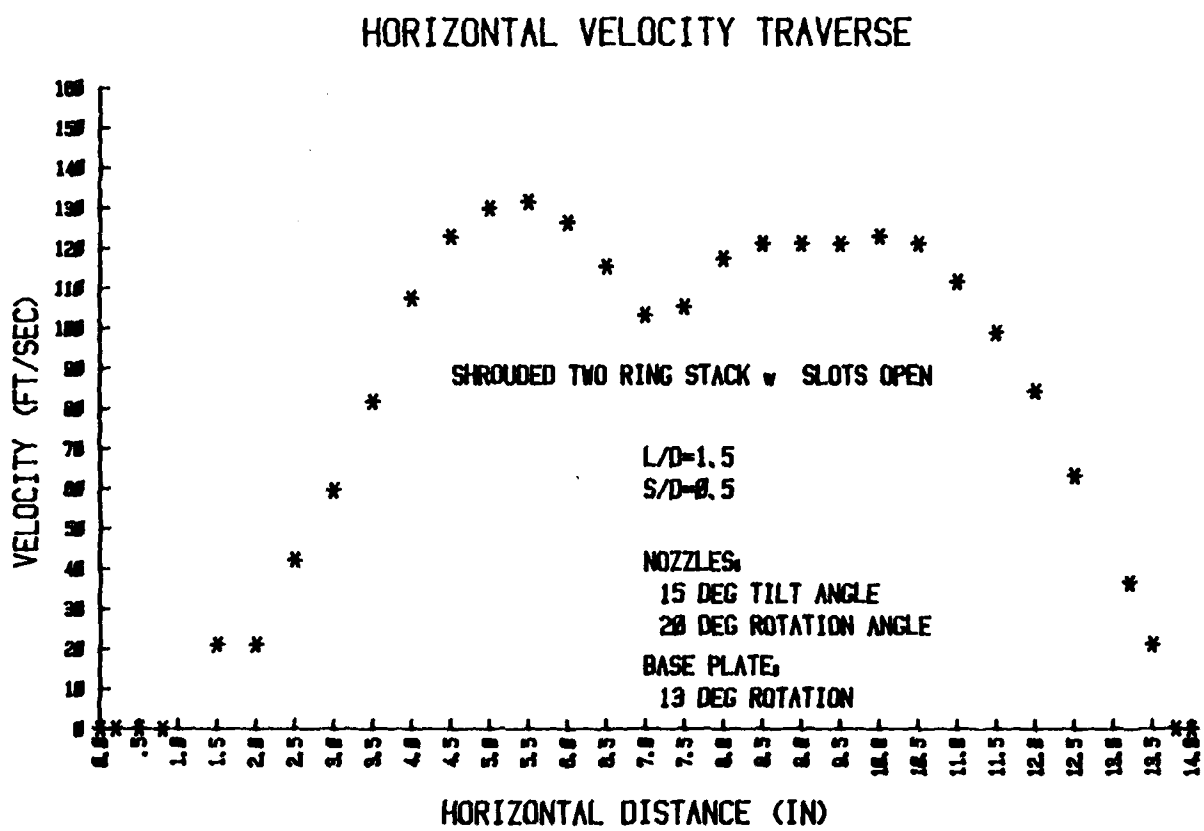



Figure 30. VTD

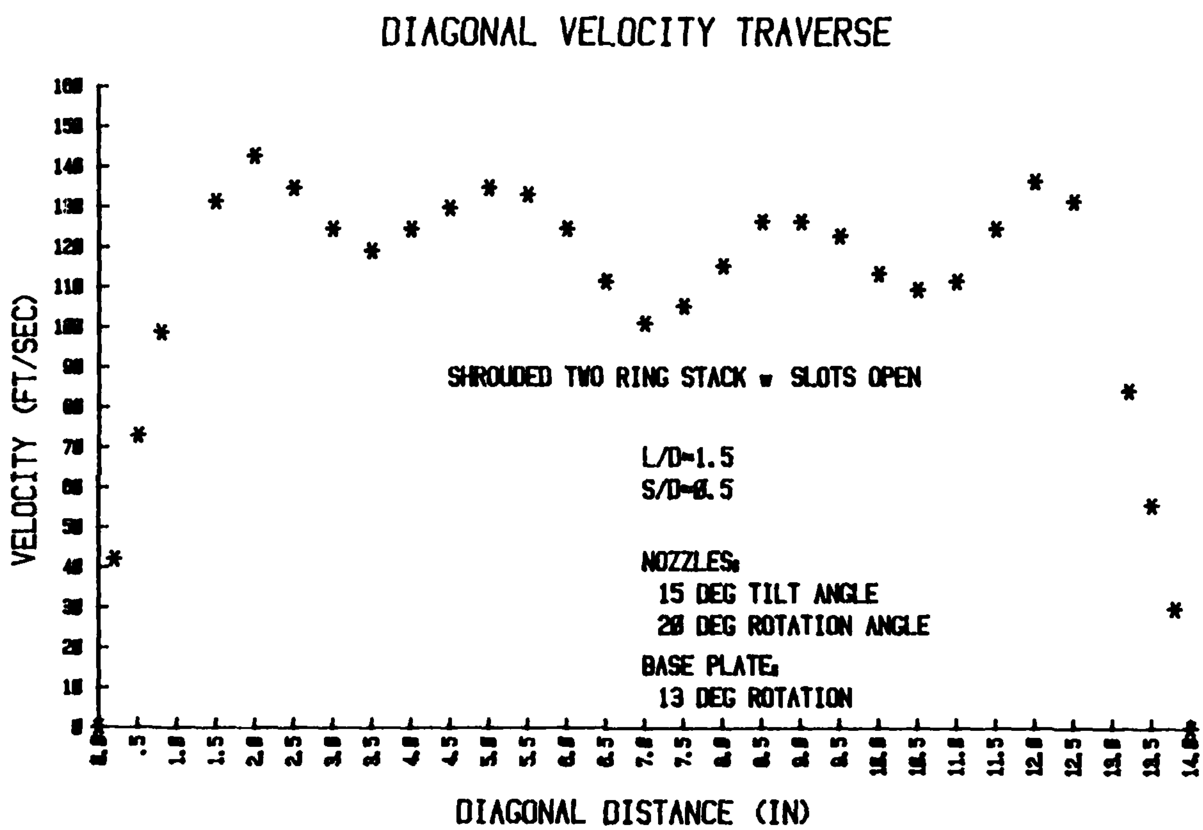



Figure 30. VTD

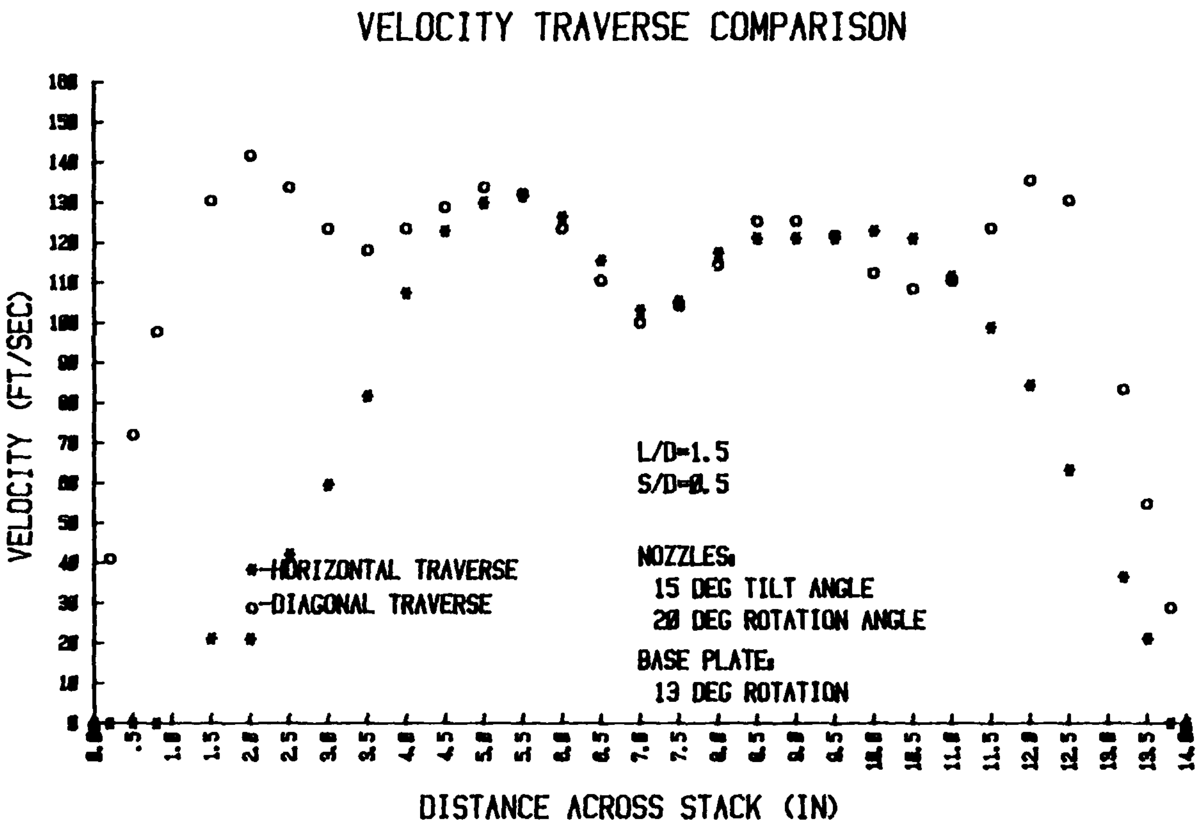



Figure 30. VTD

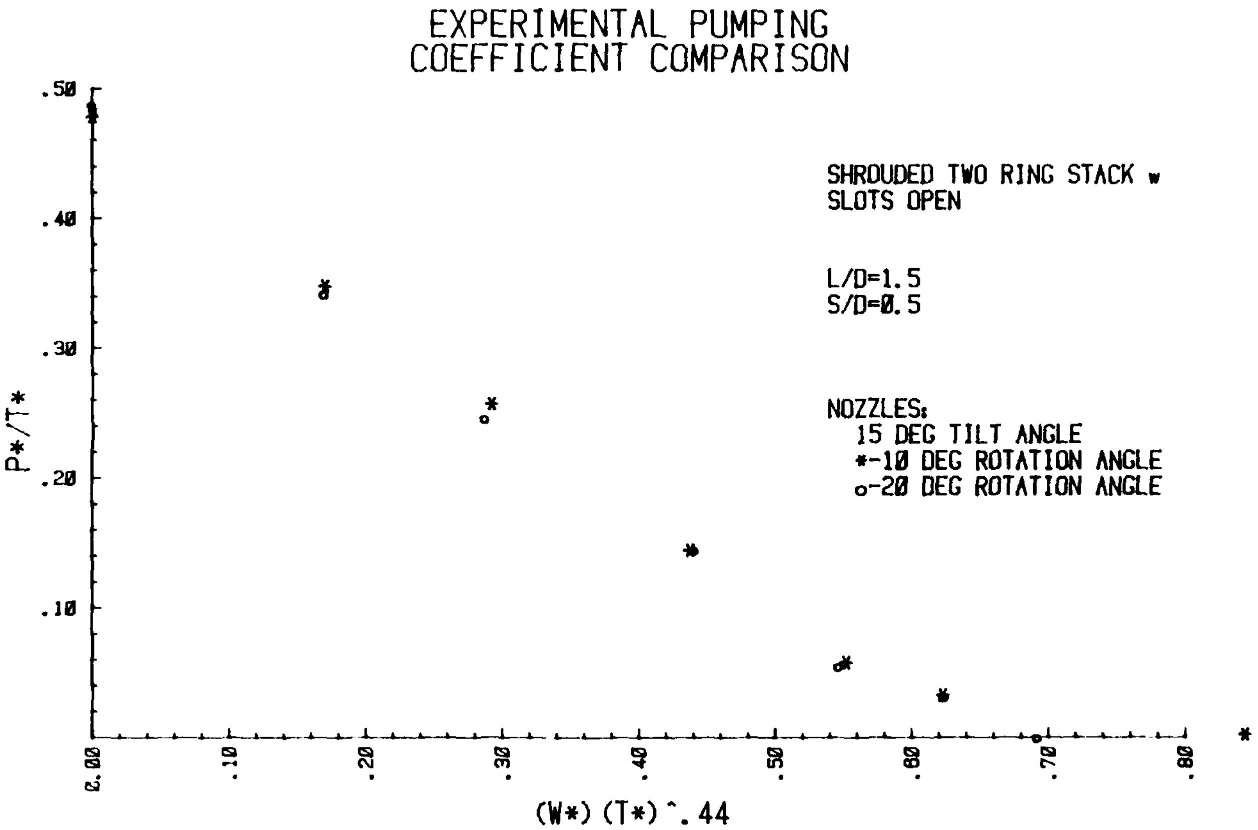



Figure 31. Slots Open: 15/10 Nozzles

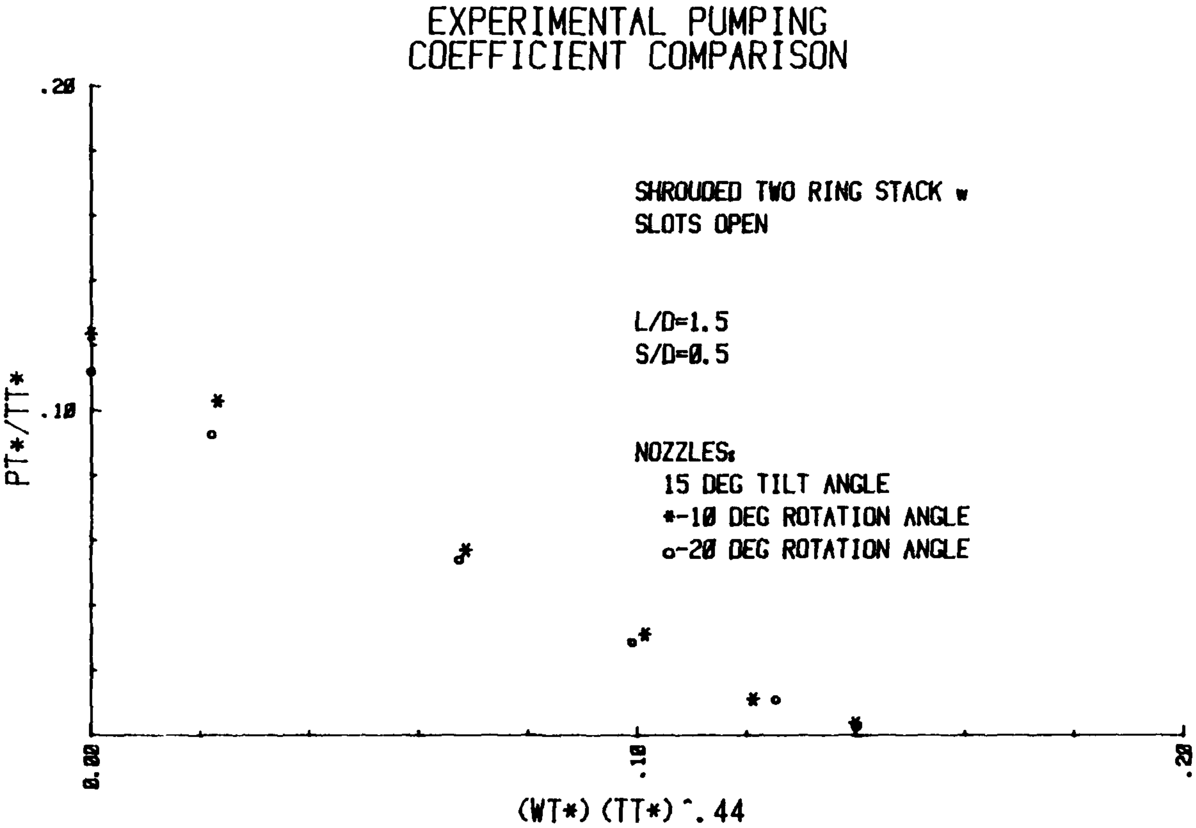



Figure 31. PCD (Tertiary)

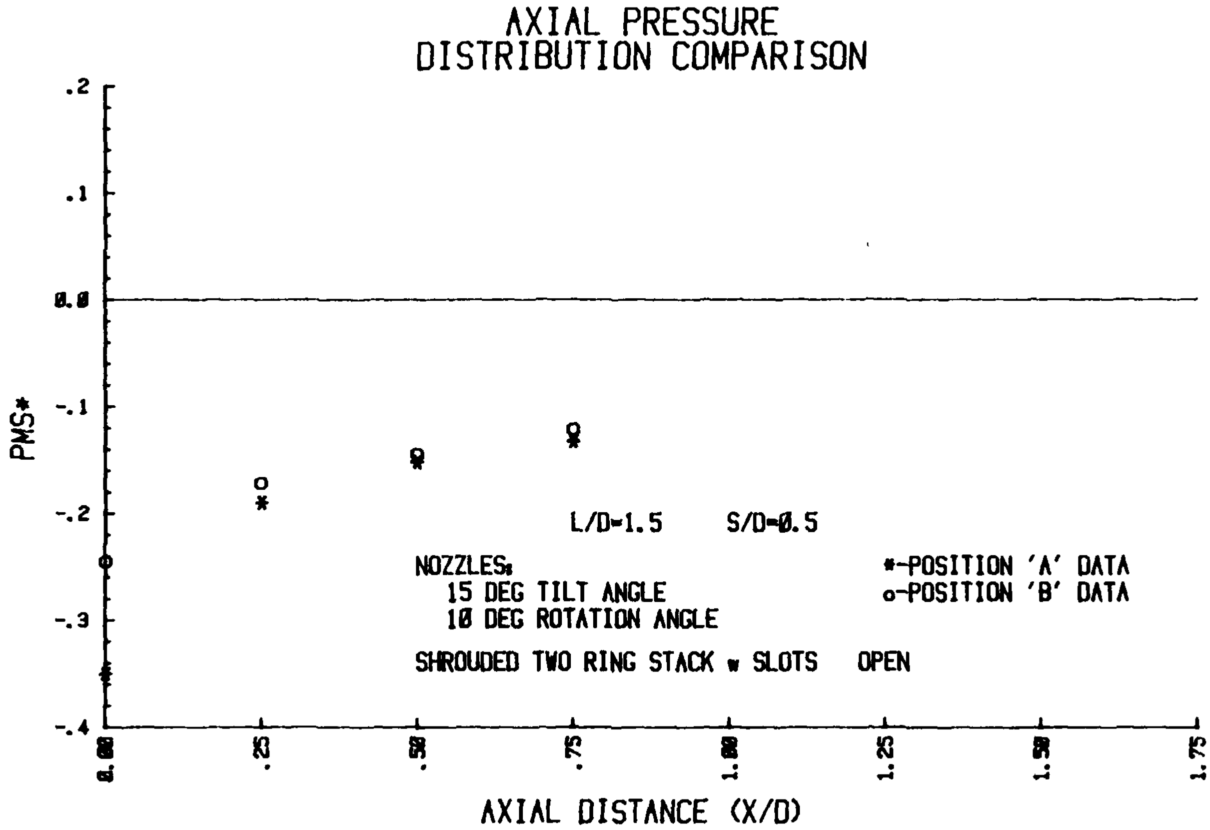



Figure 31. MSD

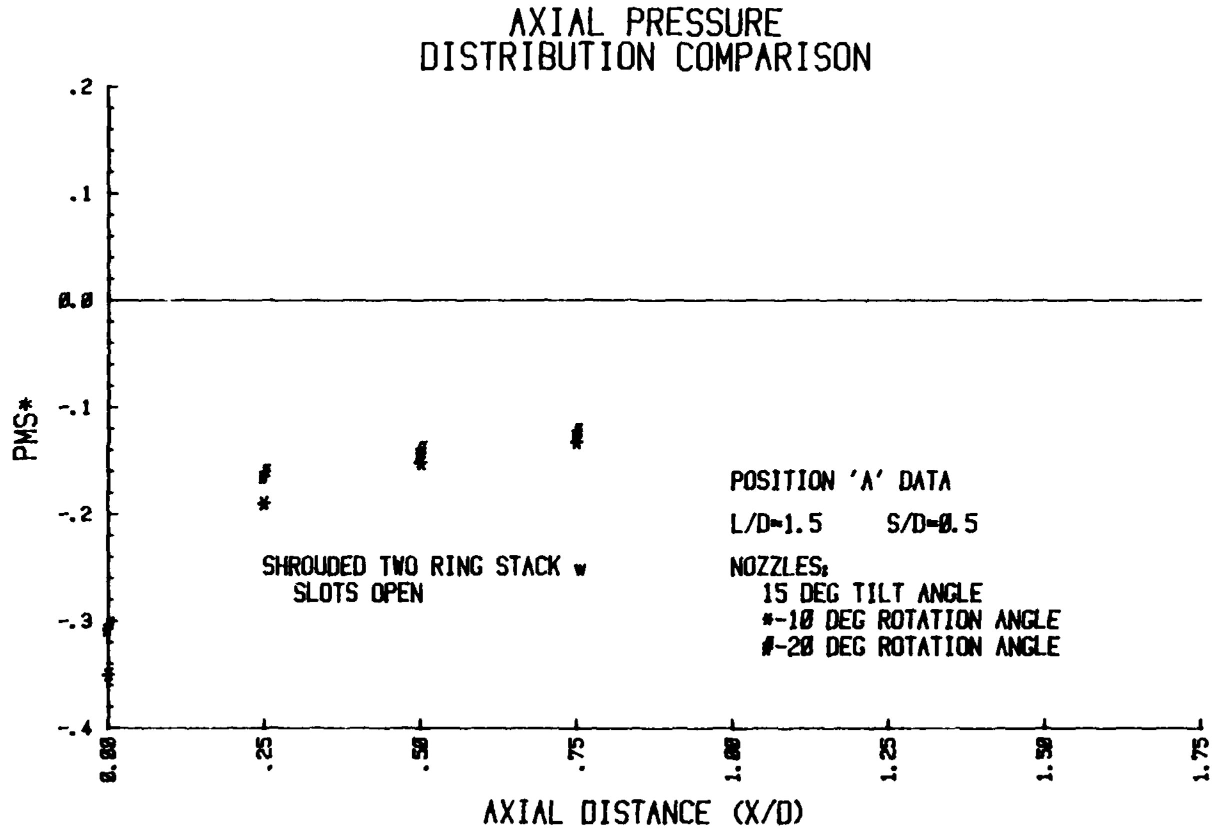



Figure 31. MSD

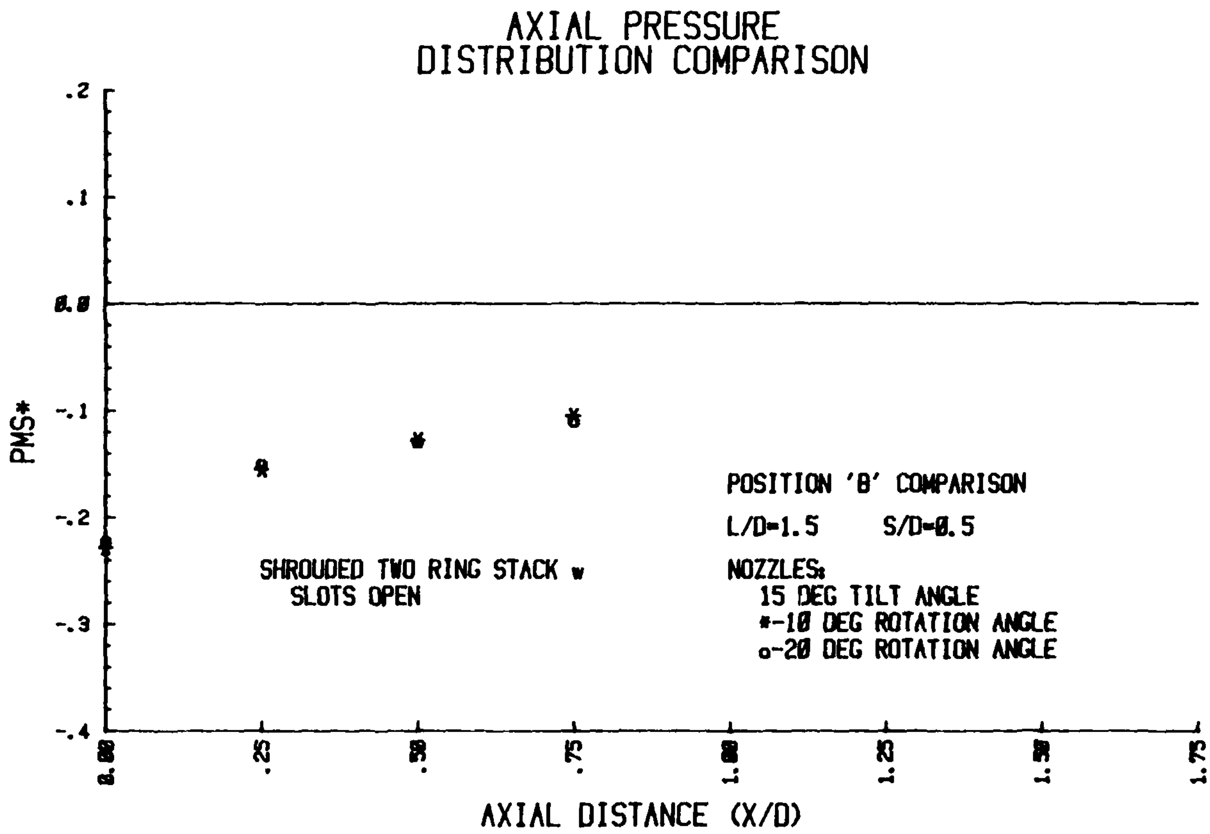



Figure 31. MSD

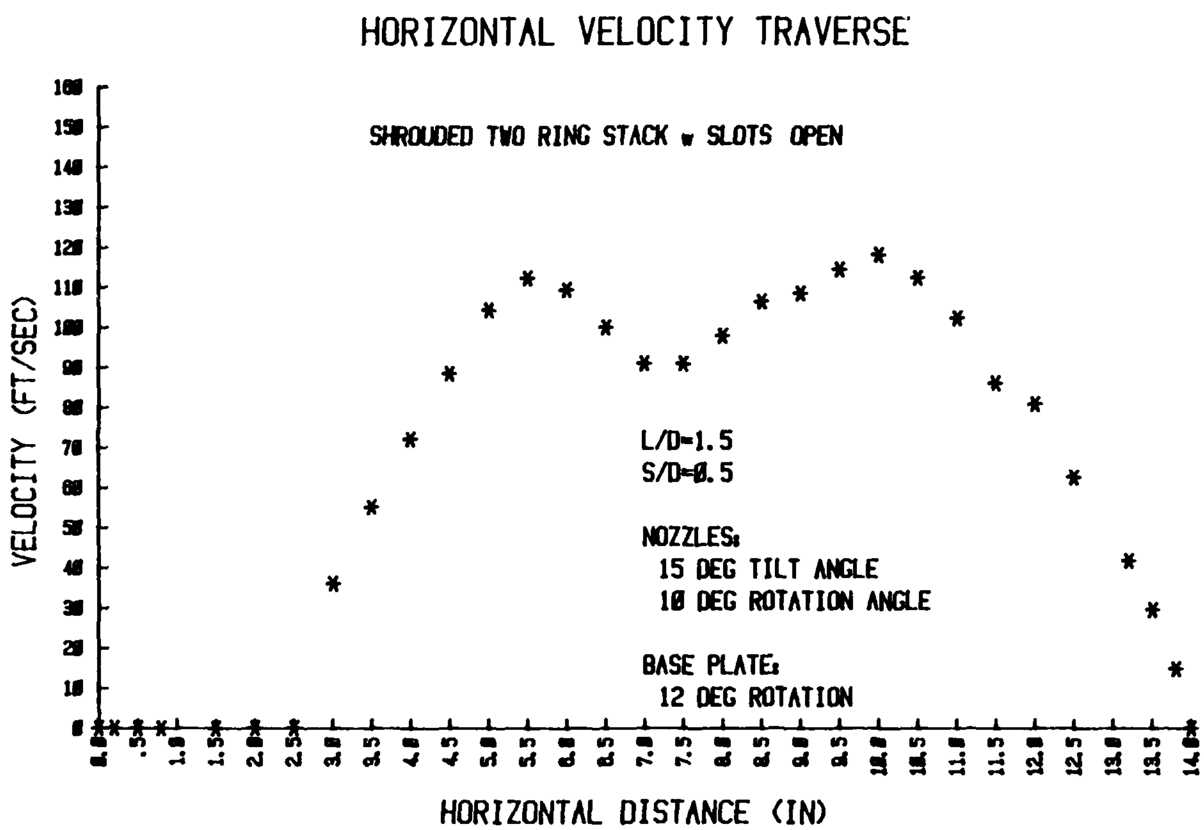



Figure 31. VTD

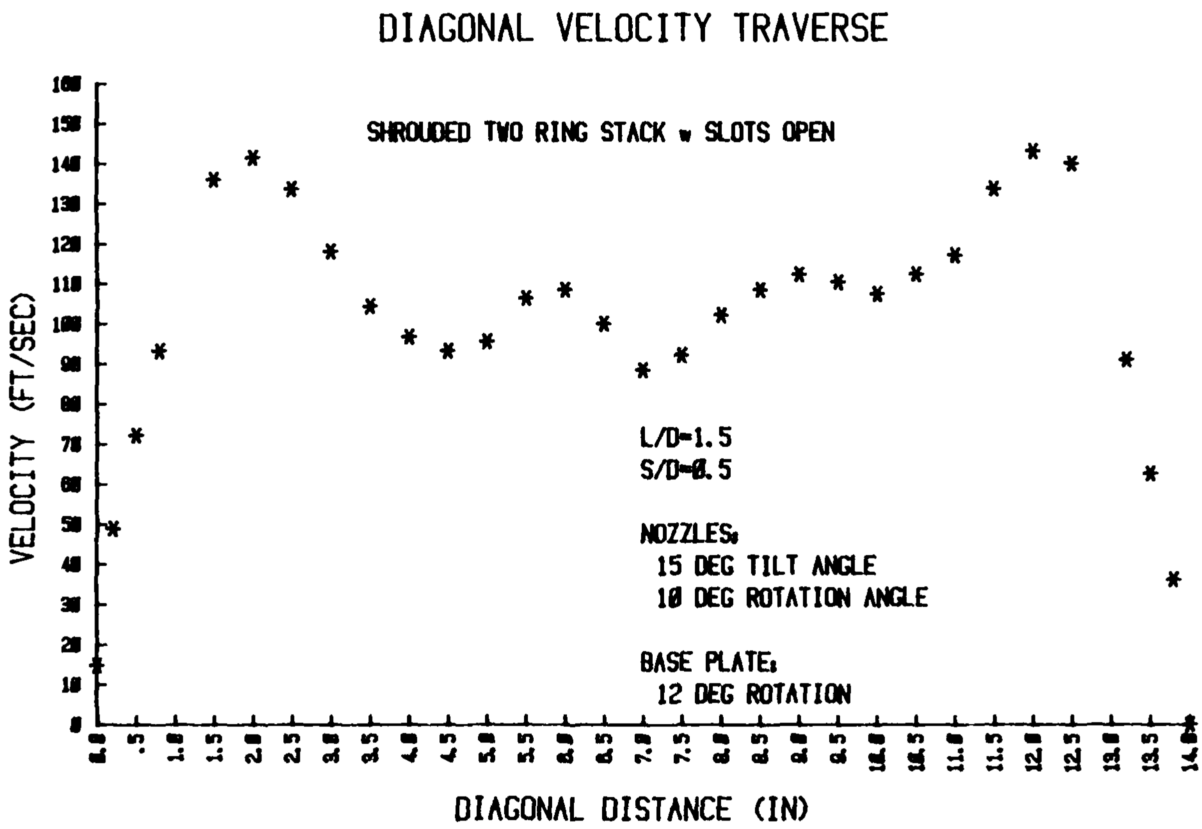



Figure 31. VTD

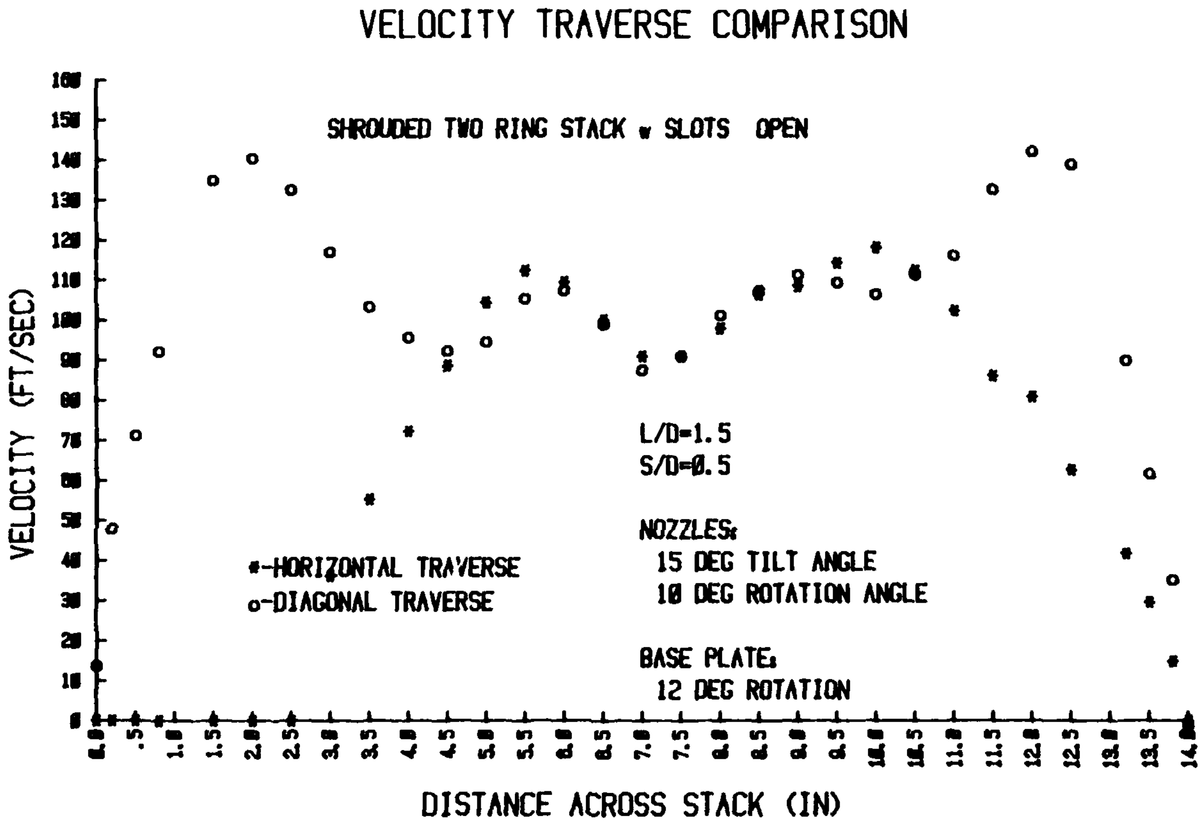



Figure 31. VTD

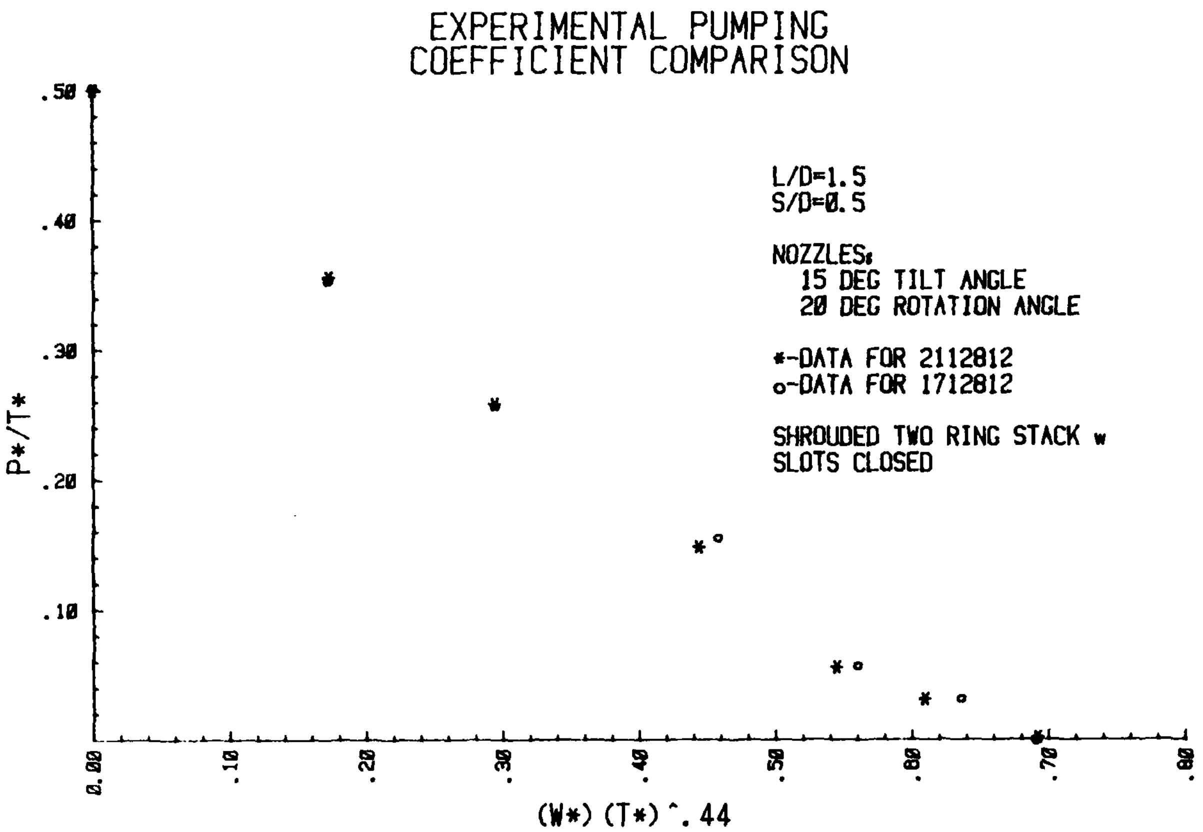



Figure 32. Slots Closed

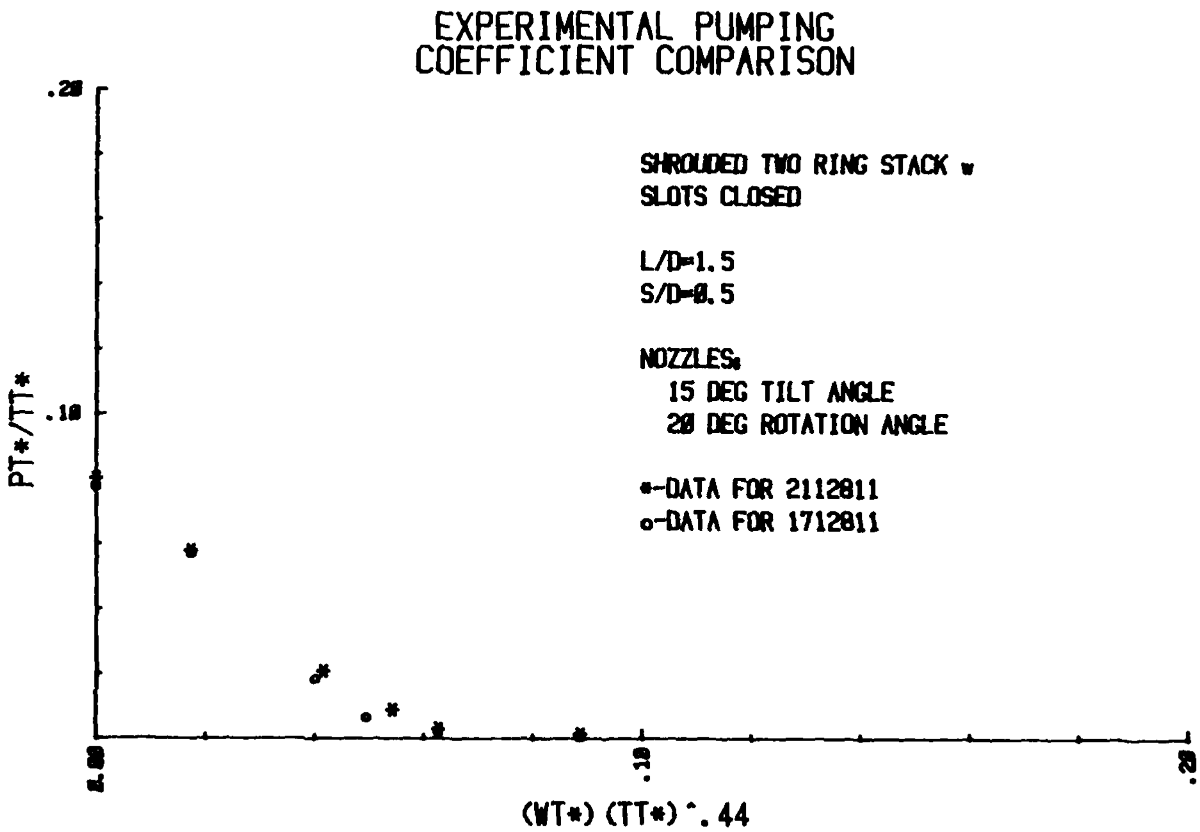



Figure 32. PCD (Tertiary)

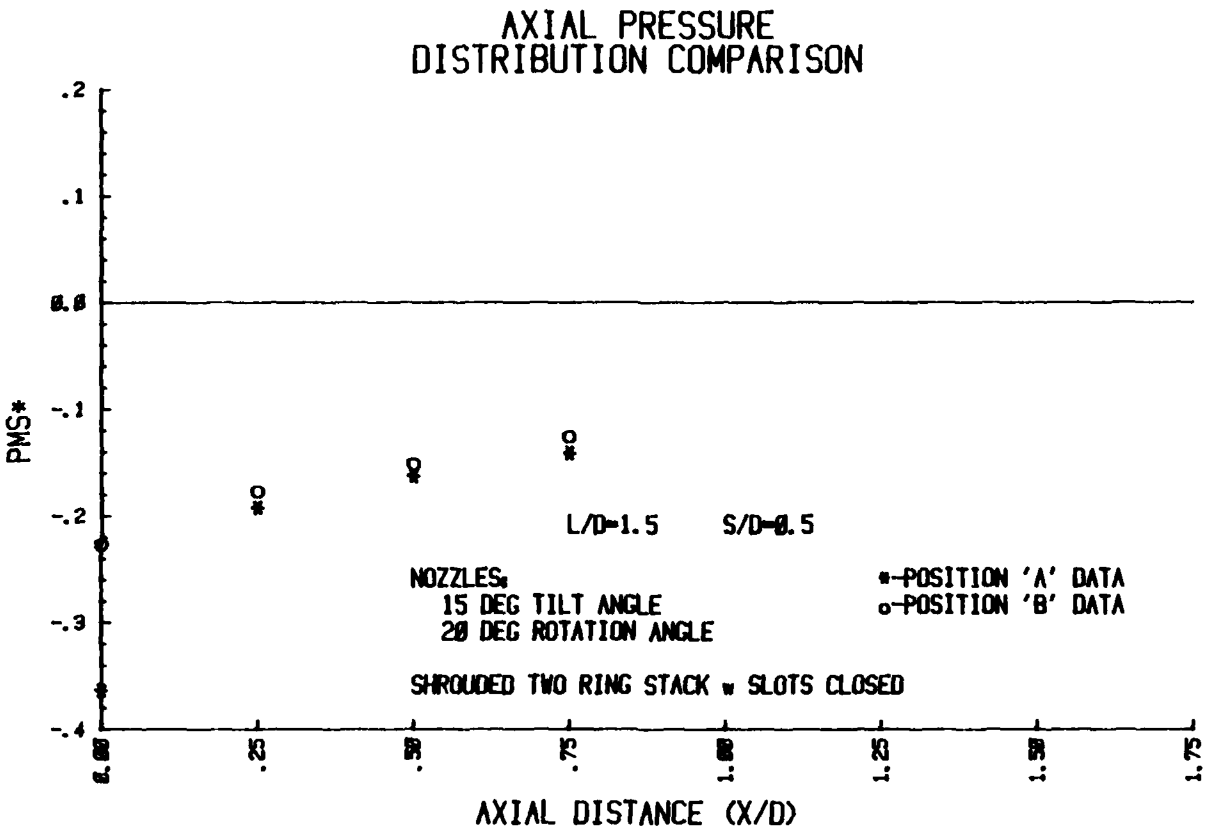



Figure 32. MSD

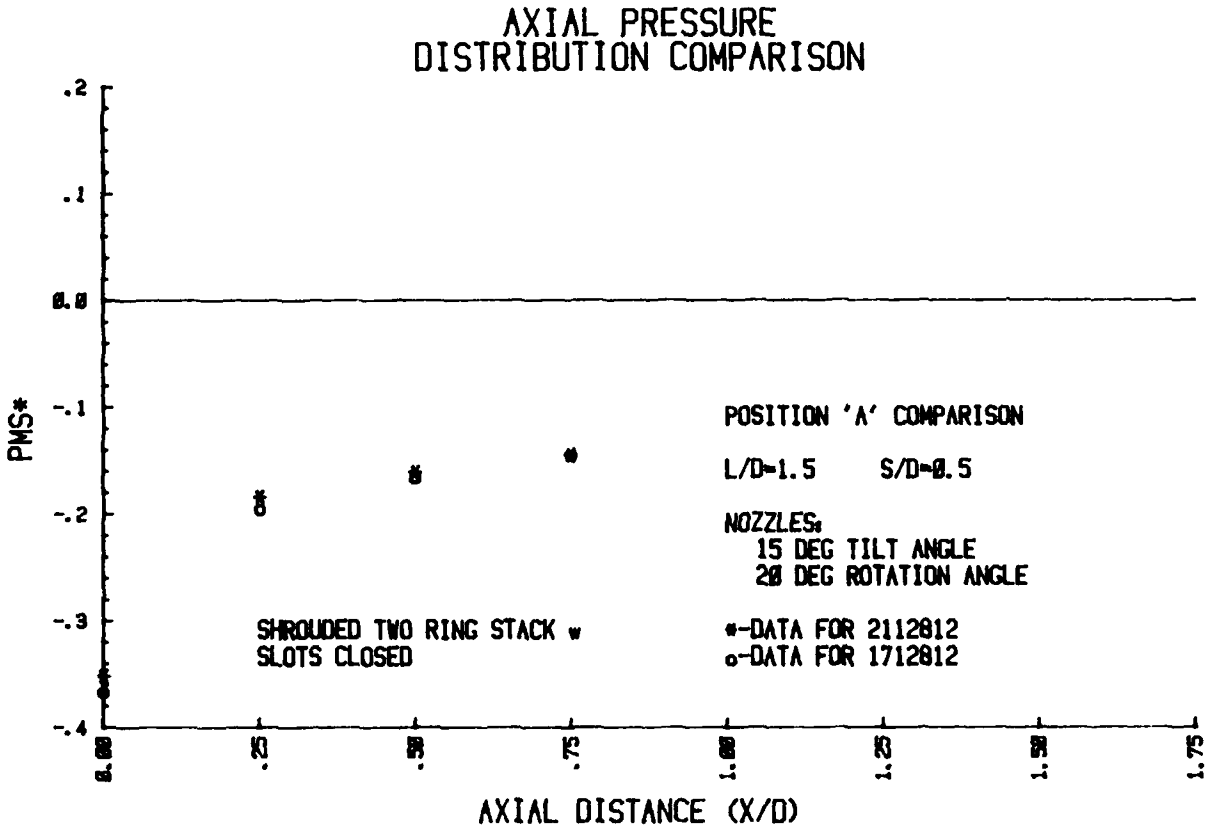



Figure 32. MSD

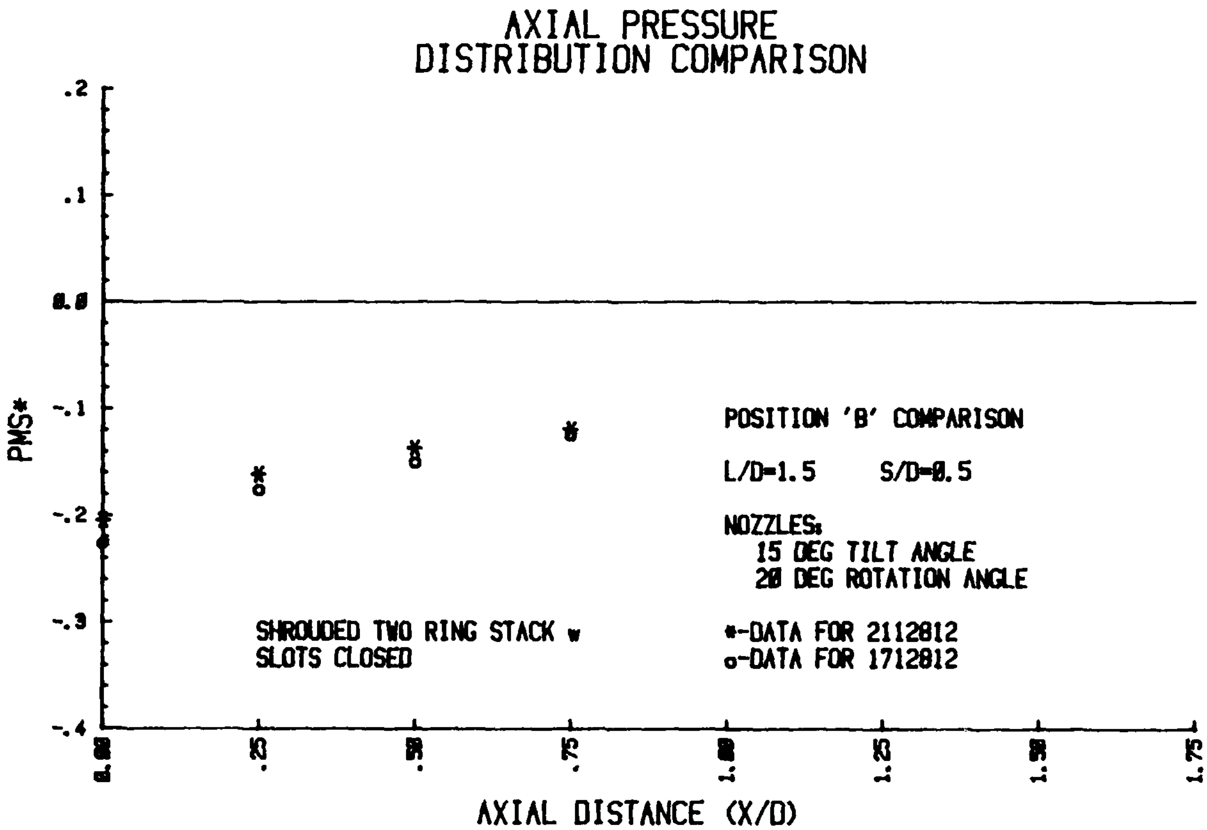



Figure 32. MSD

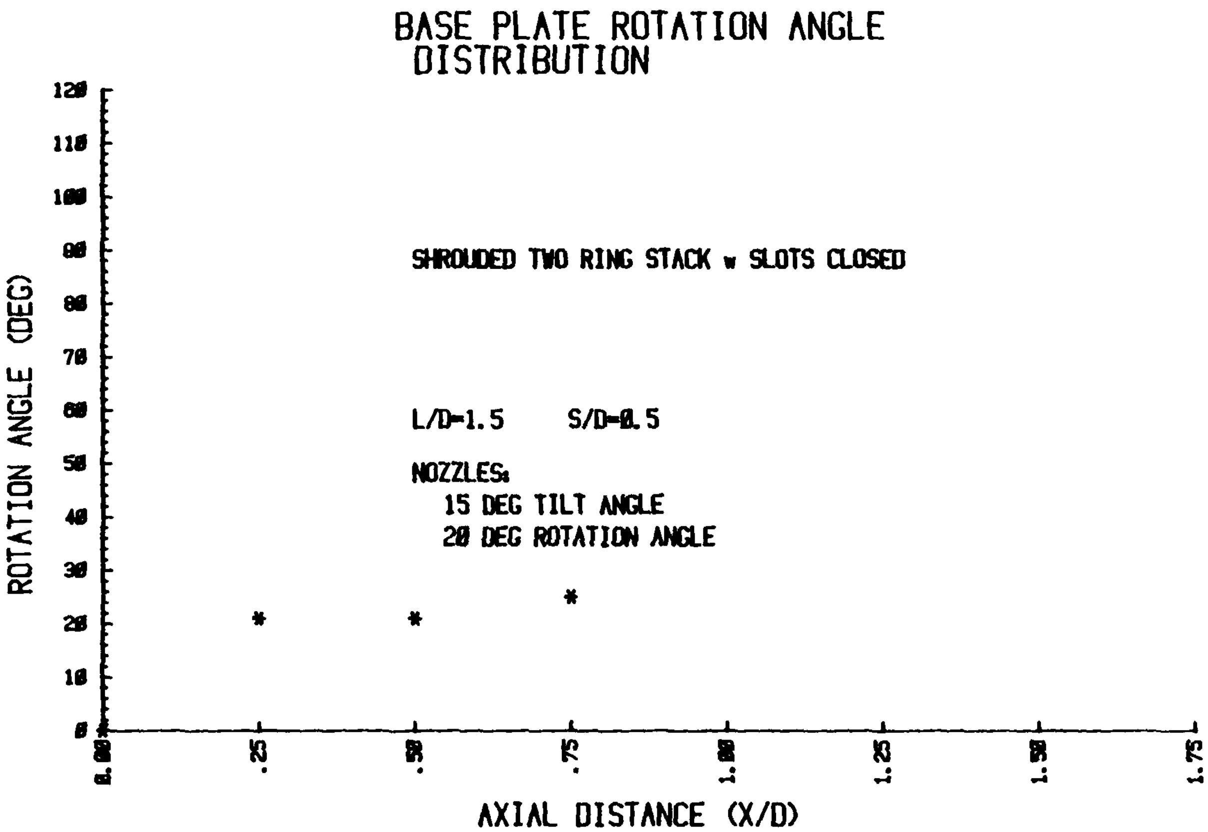



Figure 32. MSD

HORIZONTAL VELOCITY TRAVERSE

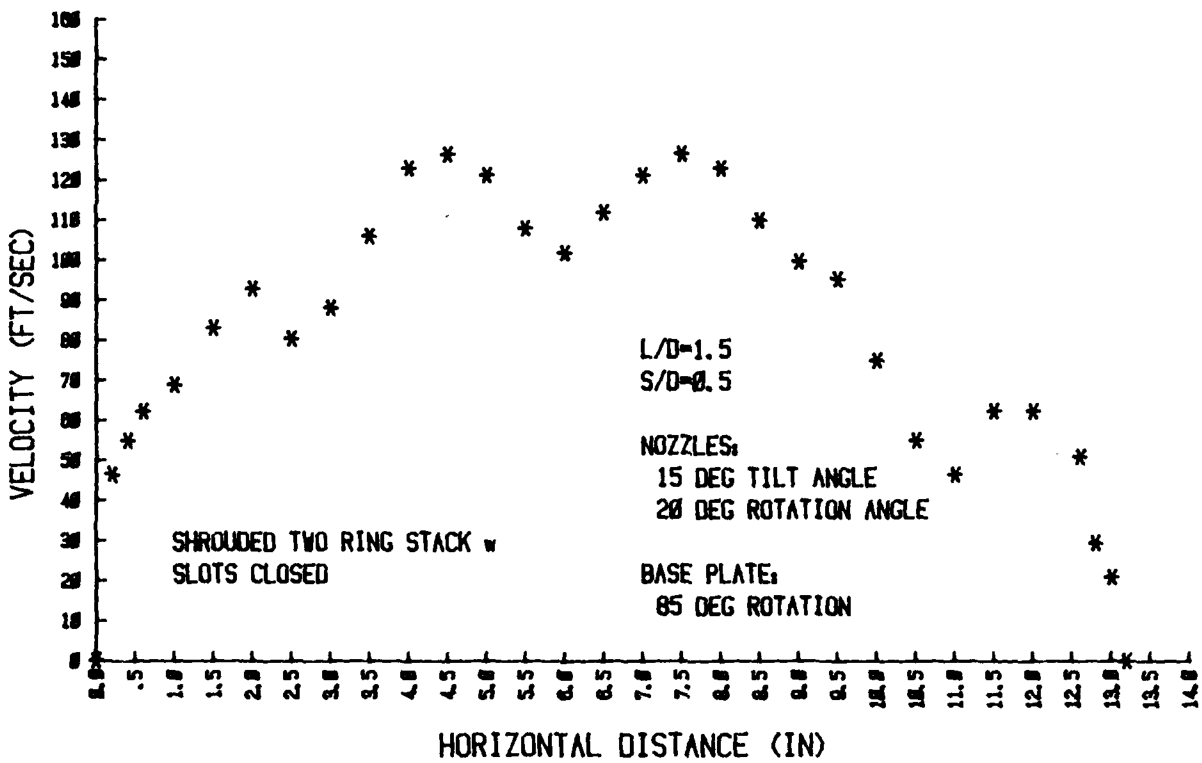



Figure 32. VTD

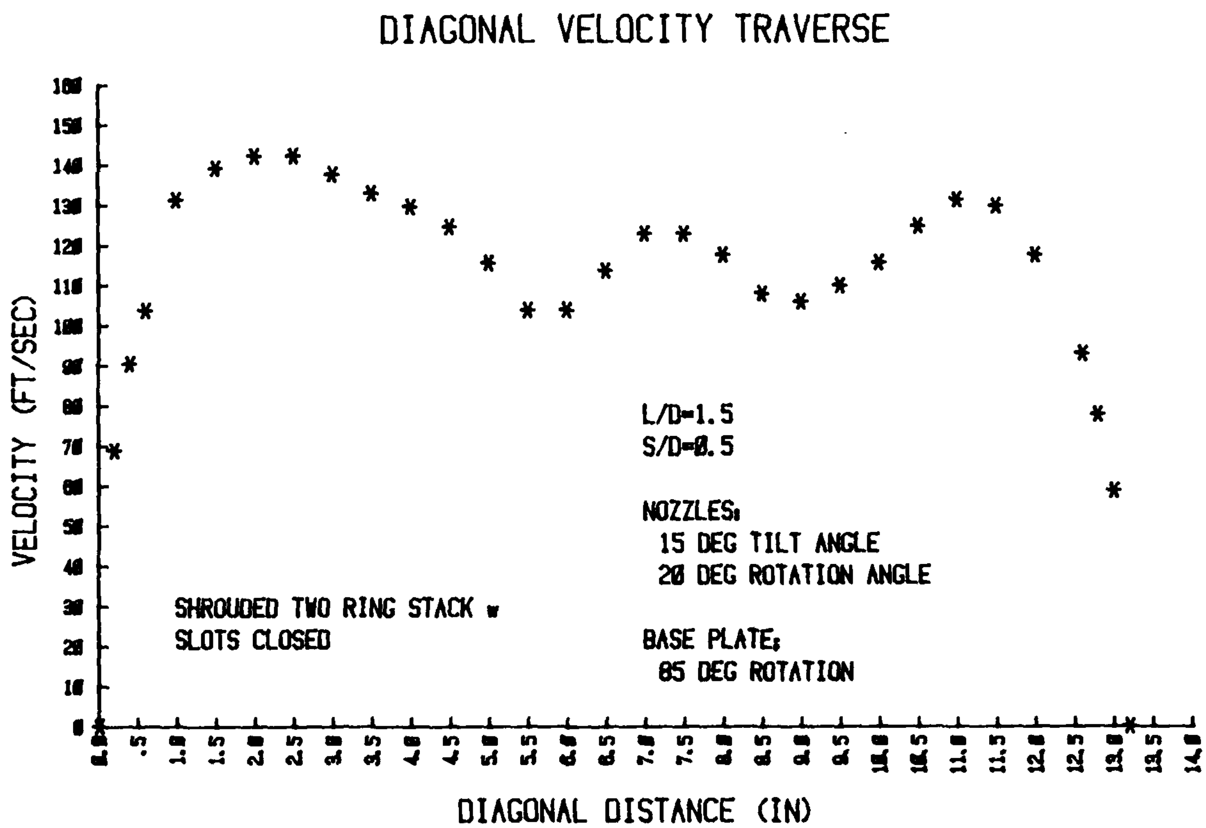



Figure 32. VTD

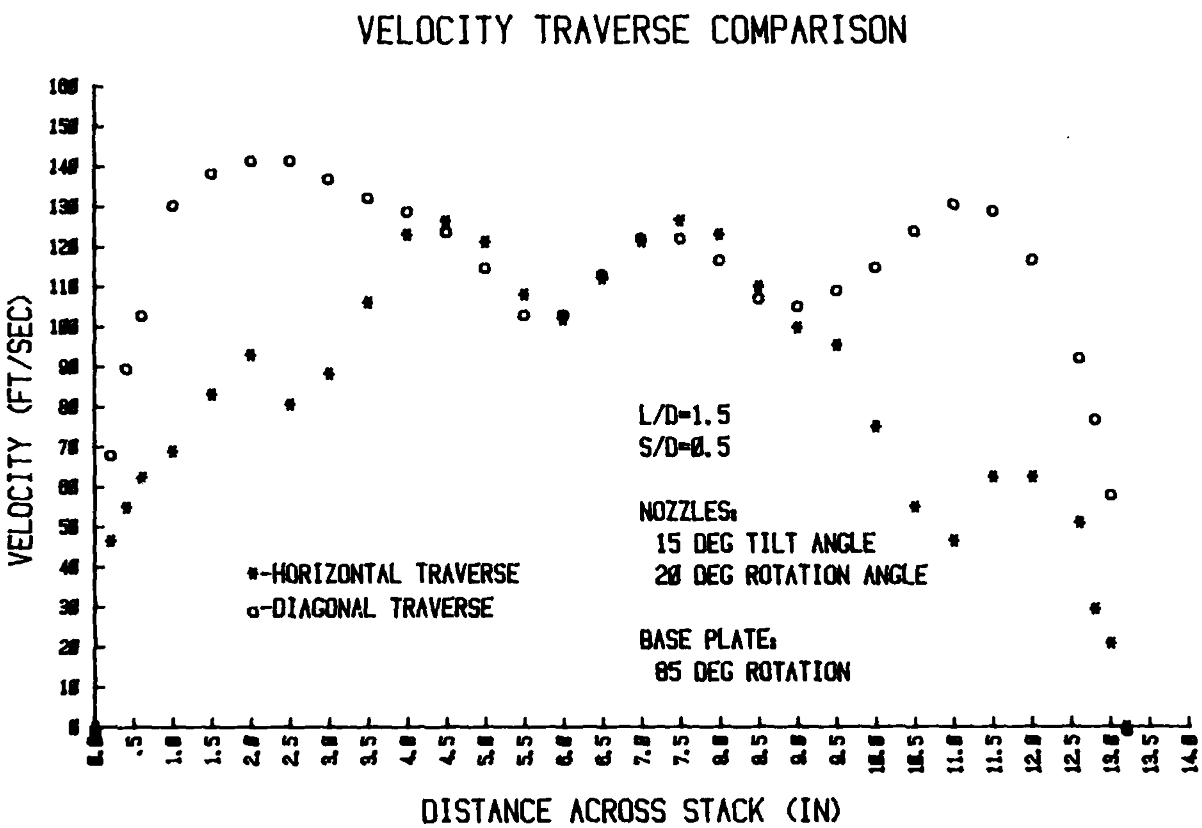



Figure 32. VTD

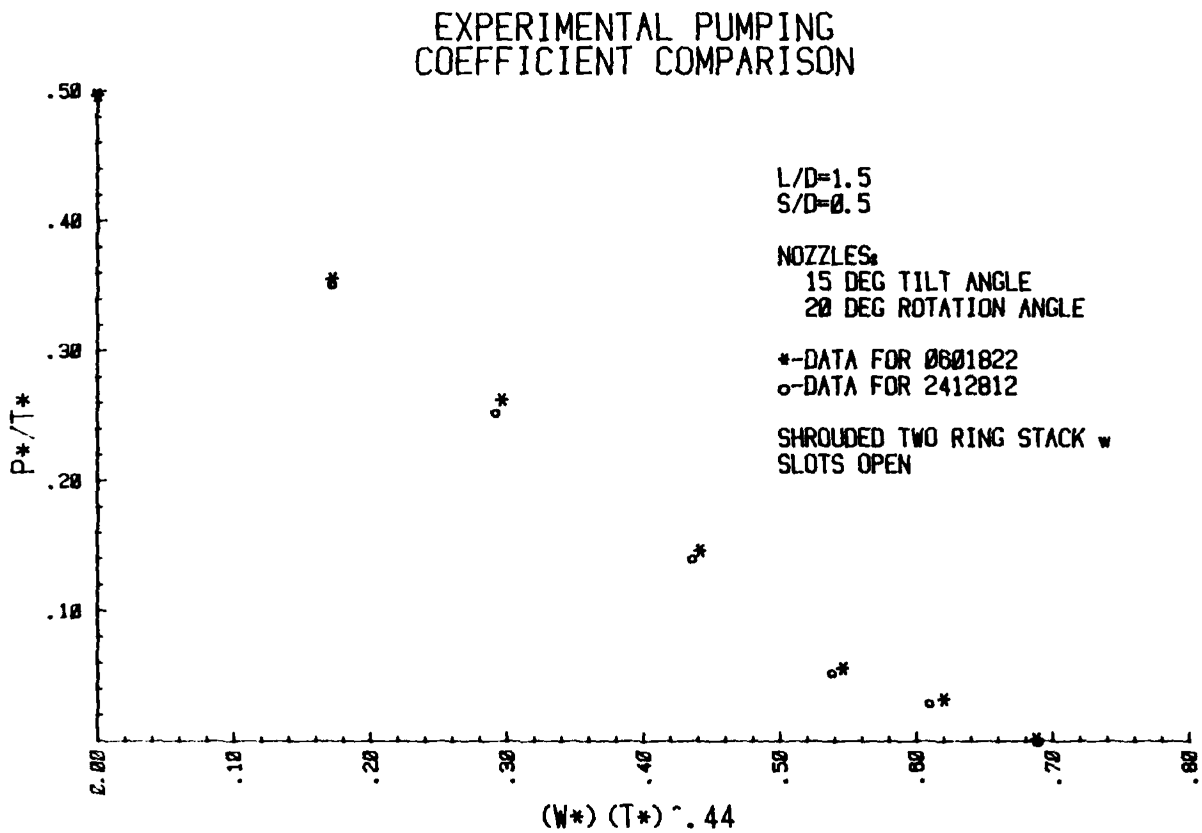



Figure 33. Slots Open

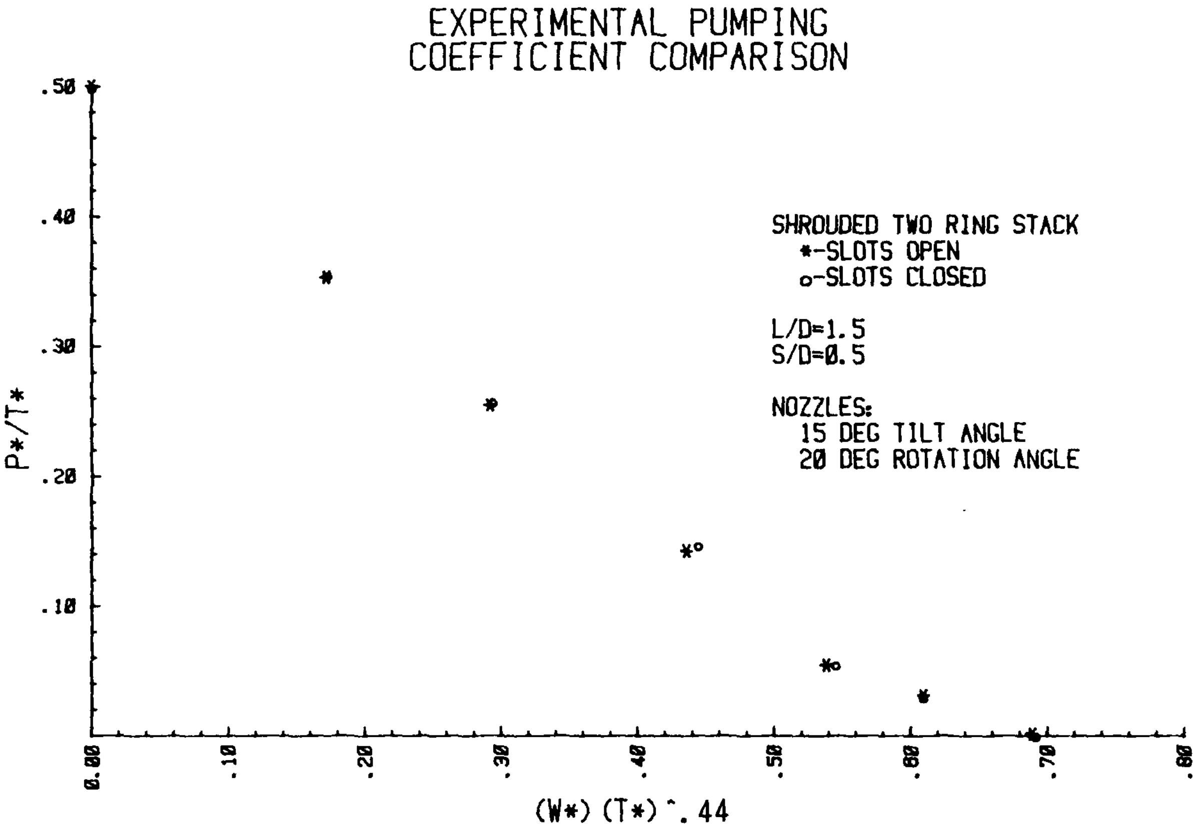



Figure 33. PCD (Secondary)

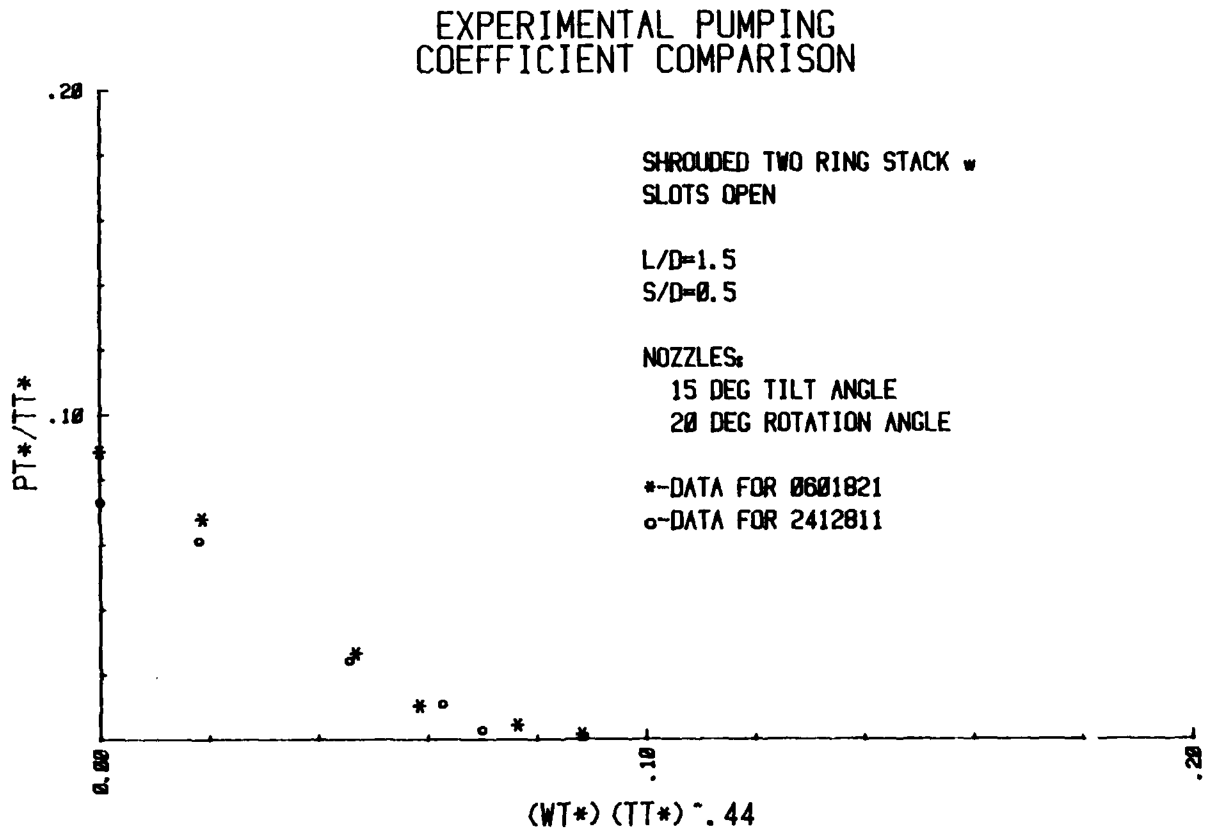



Figure 33. PCD (Tertiary)

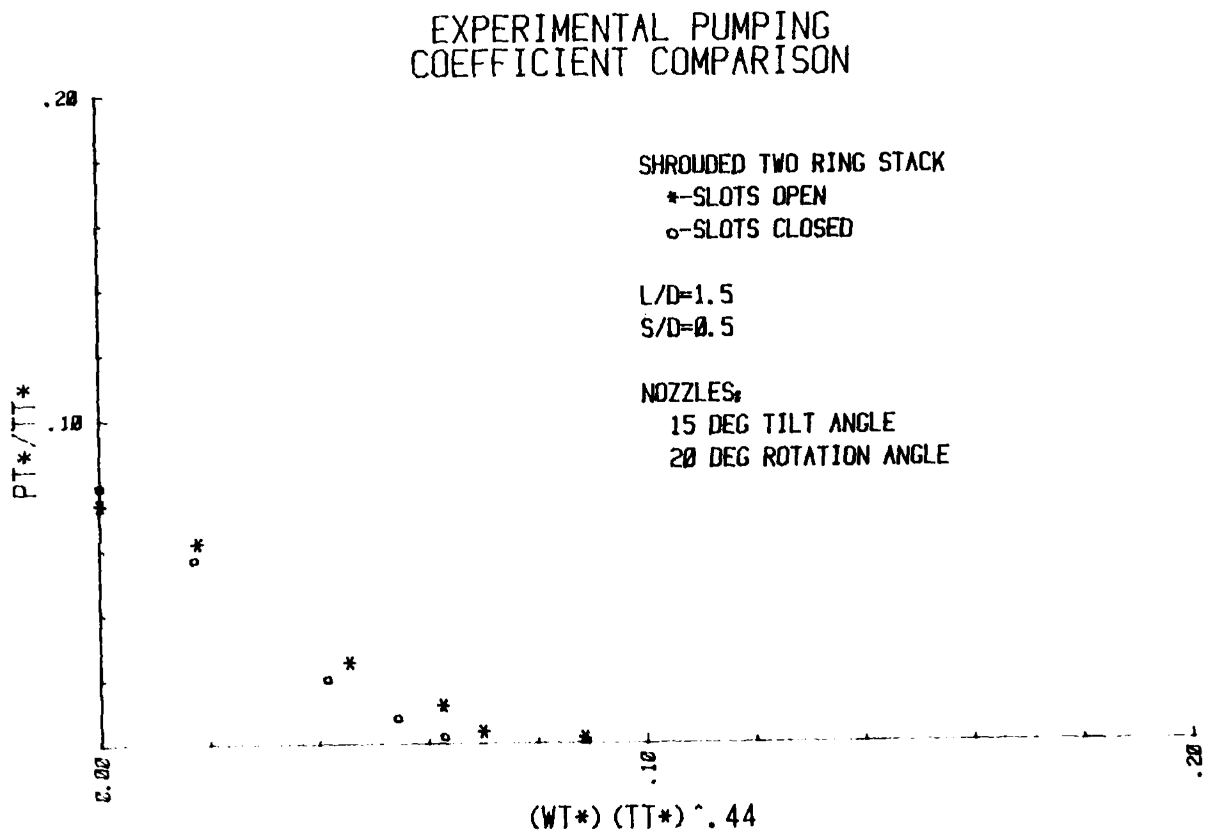



Figure 33. PCD (Tertiary)

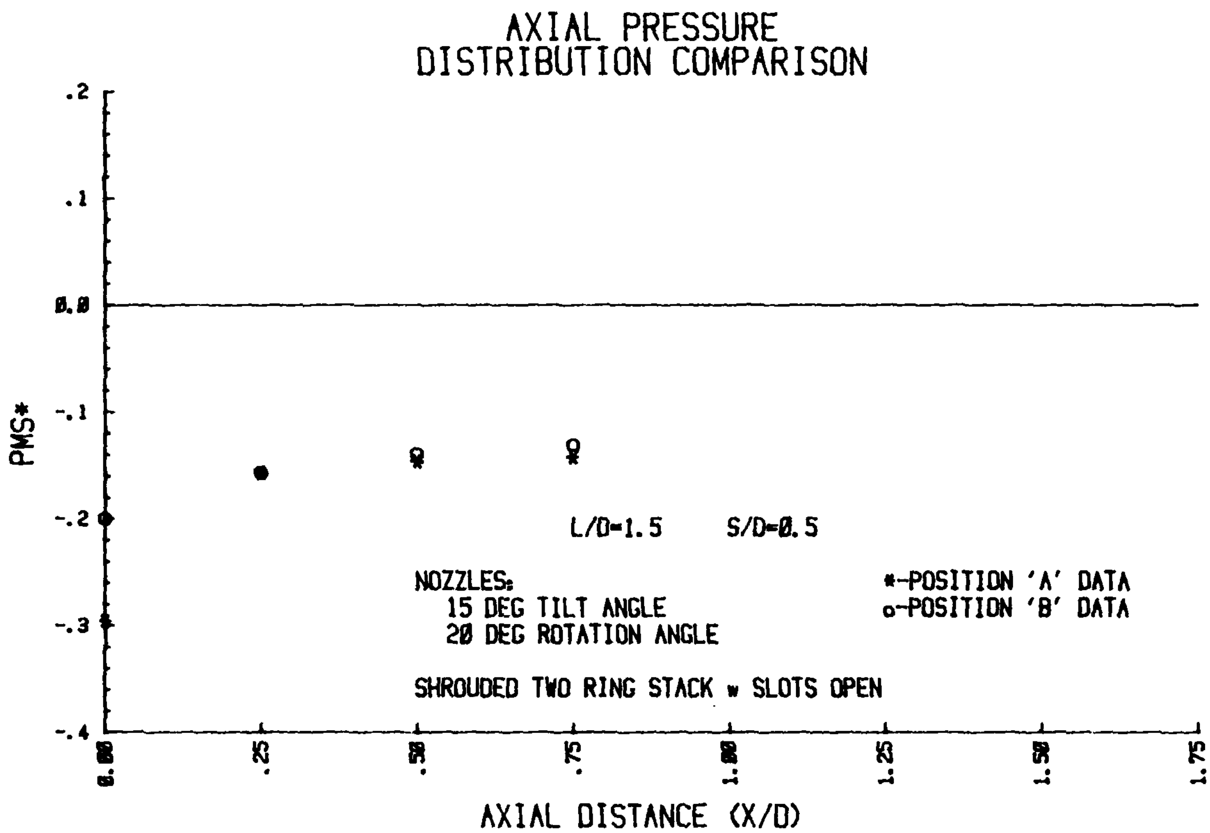



Figure 33. MSD

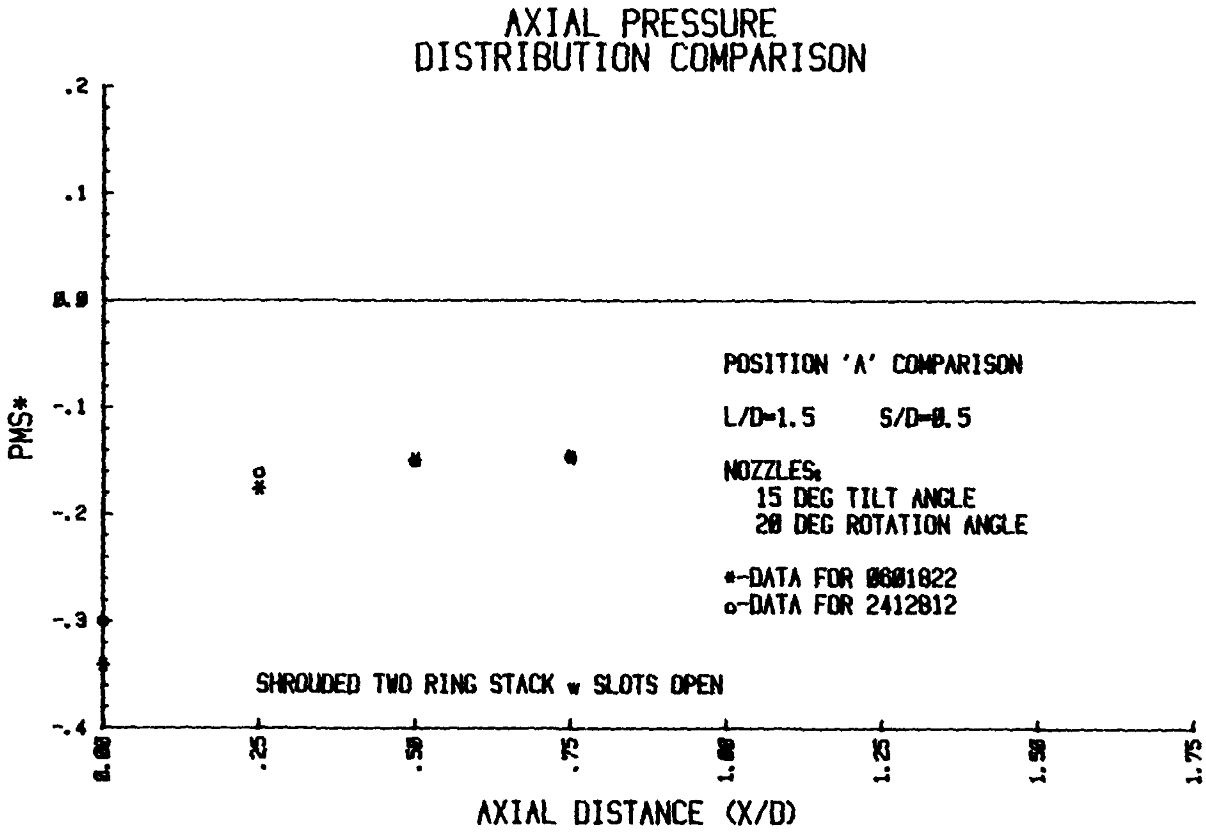



Figure 33. MSD

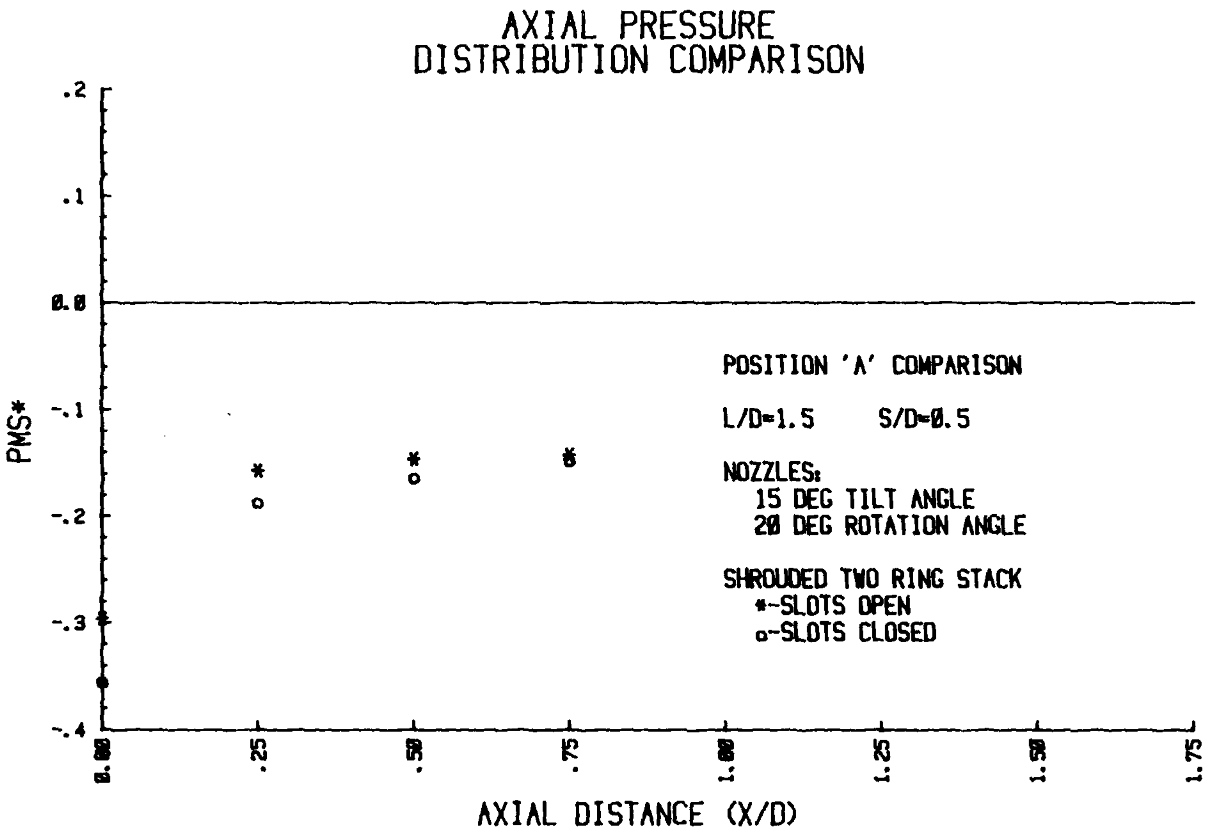



Figure 33. MSD

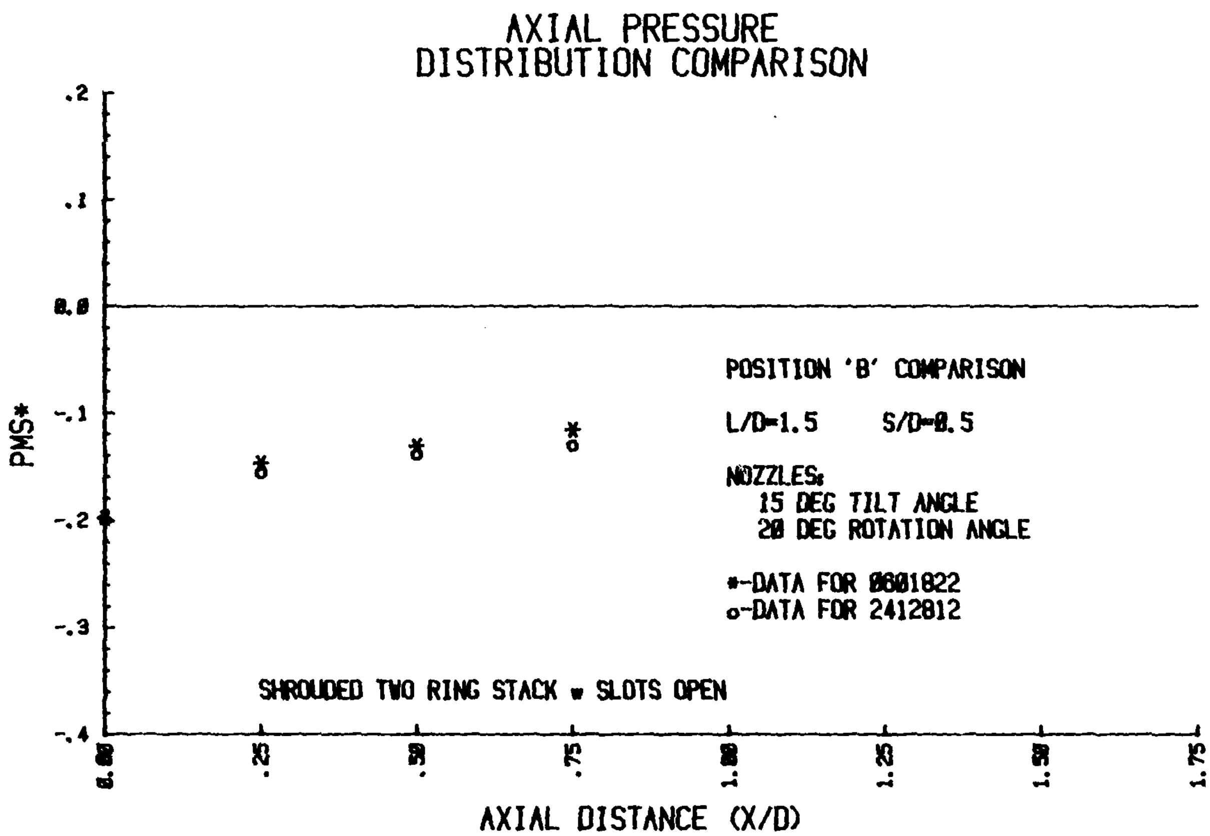



Figure 33. MSD

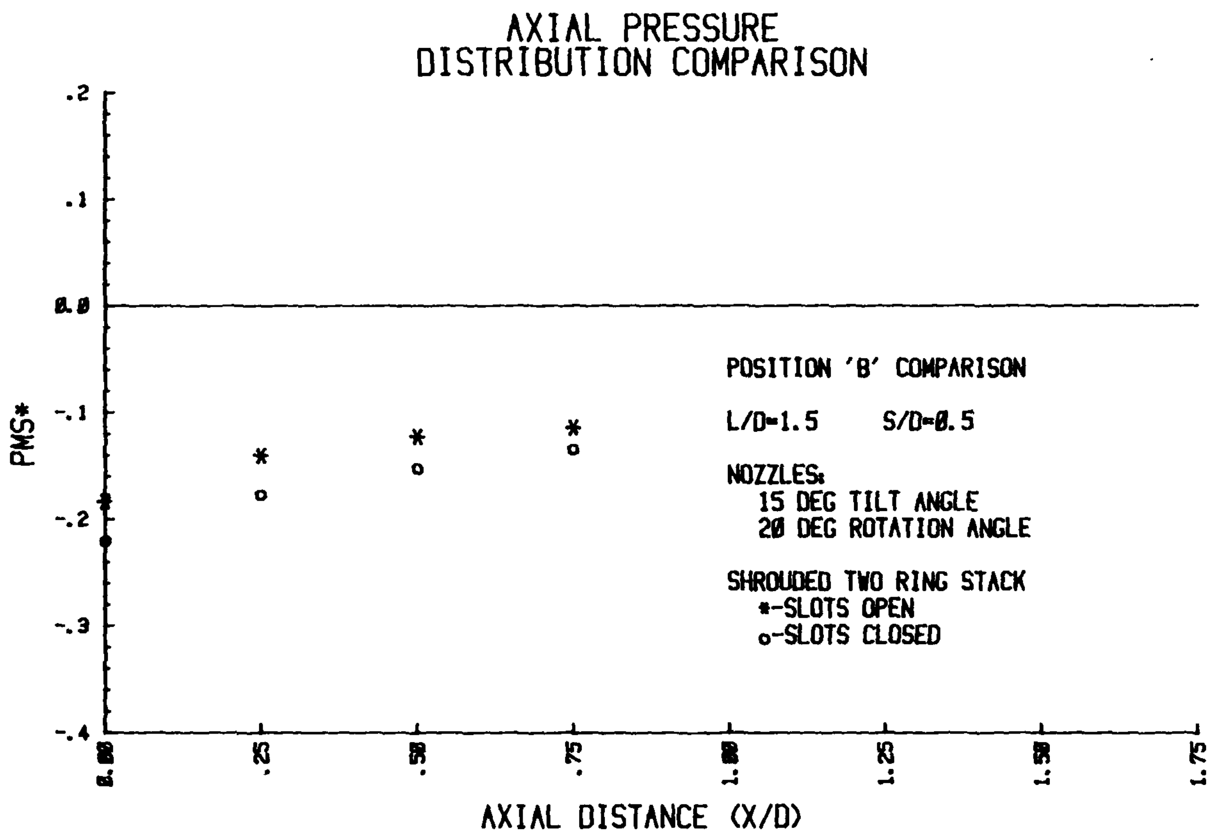



Figure 33. MSD

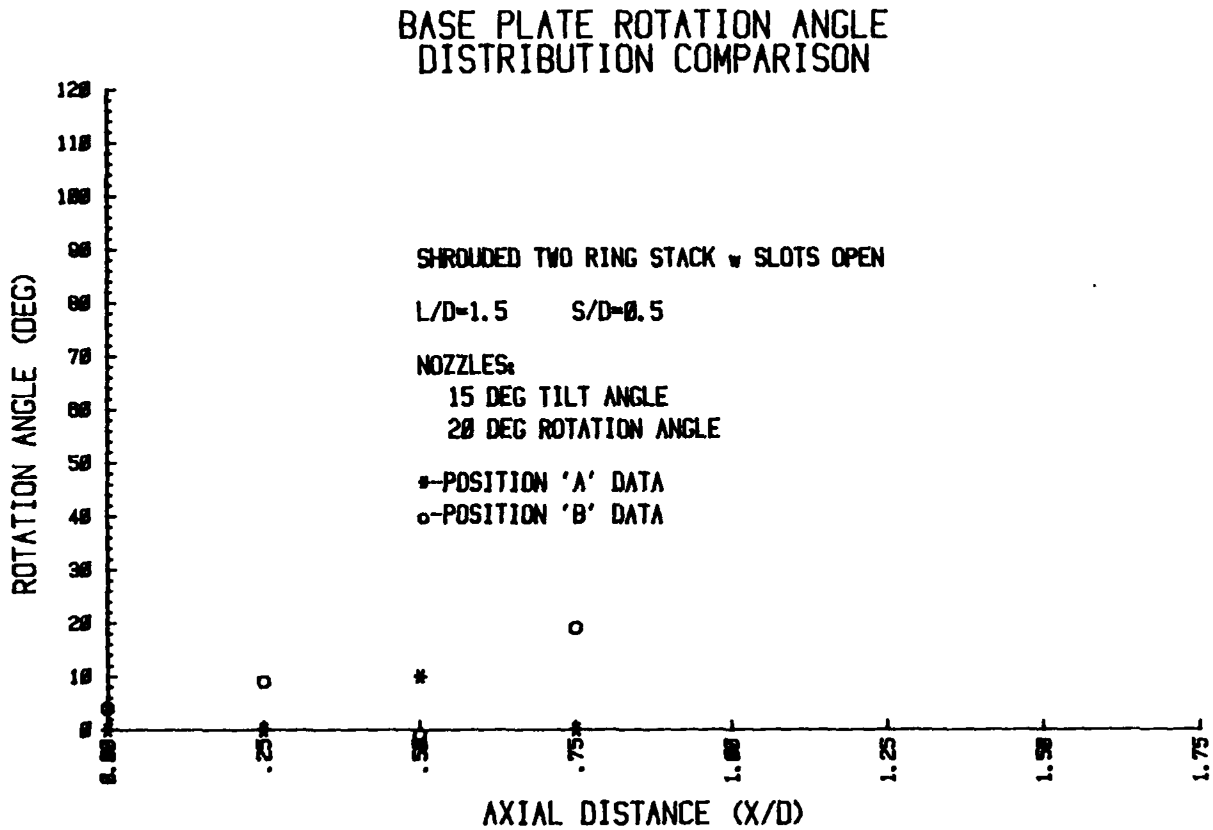



Figure 33. MSD

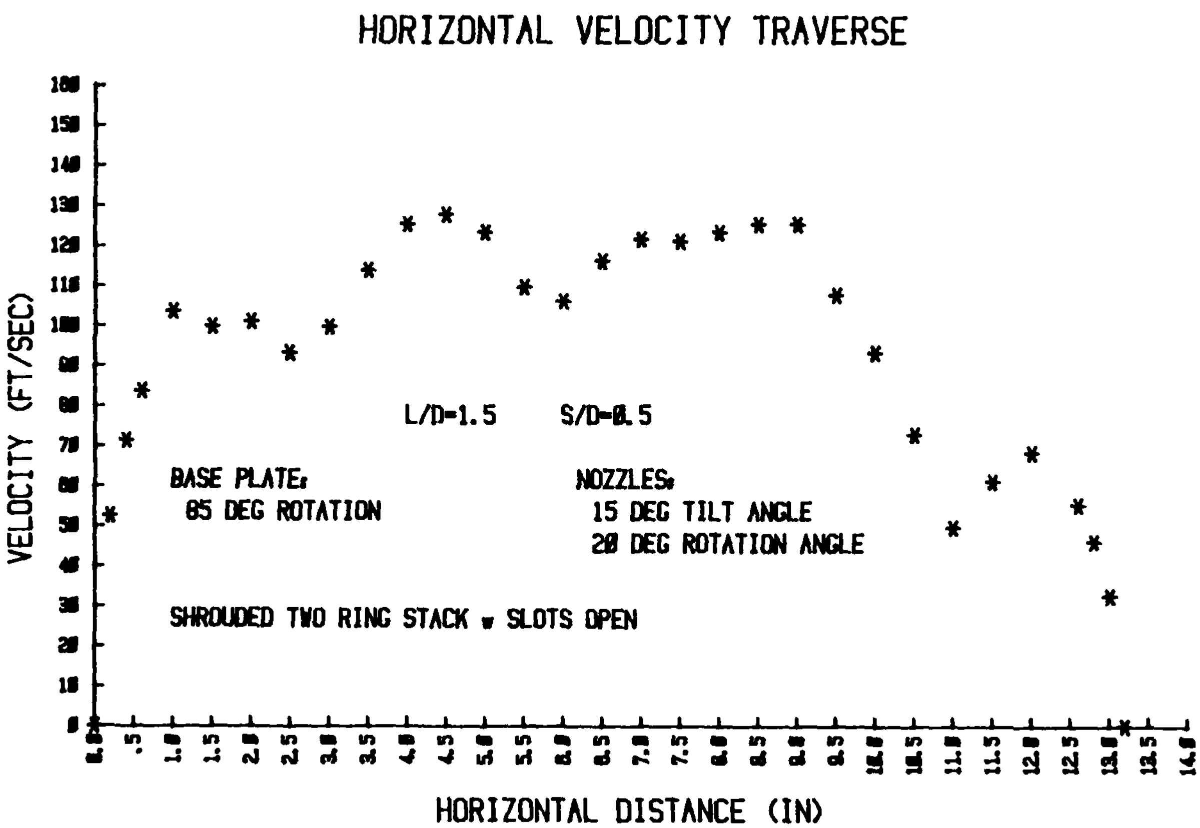



Figure 33. VTD

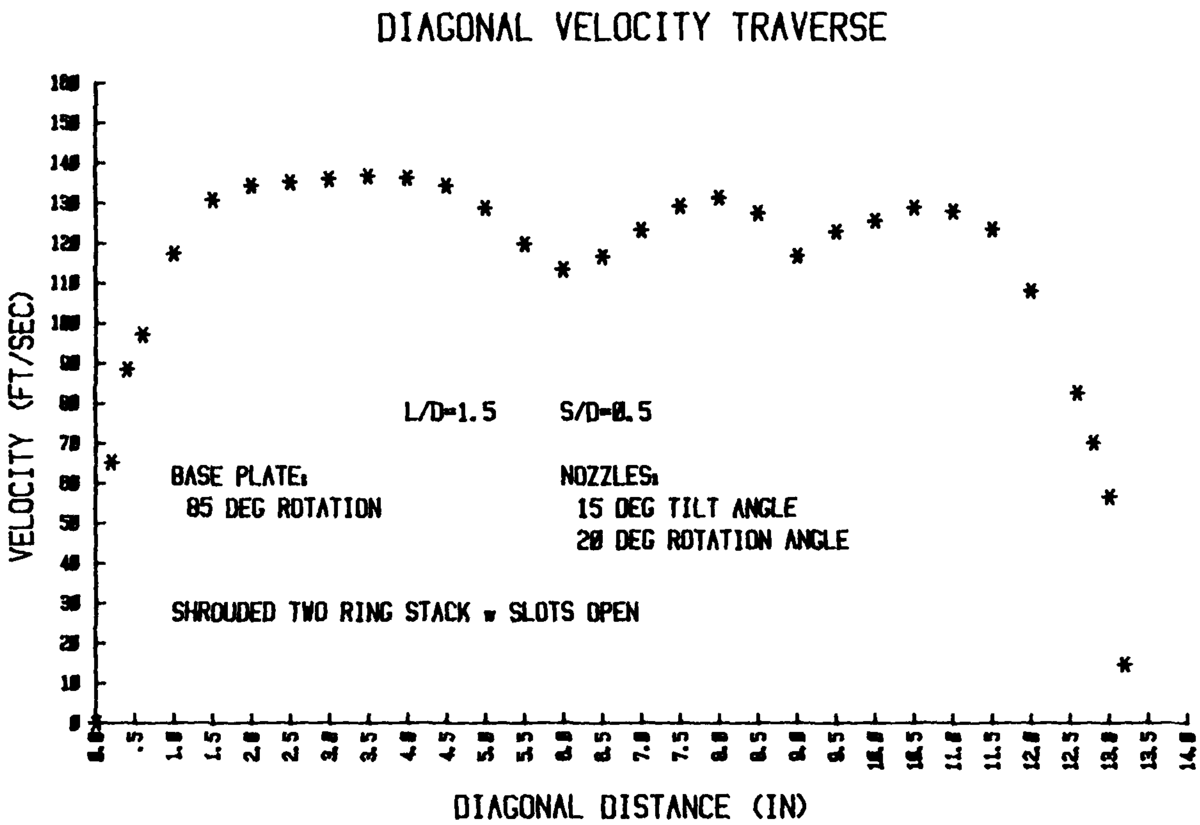



Figure 33. VTD

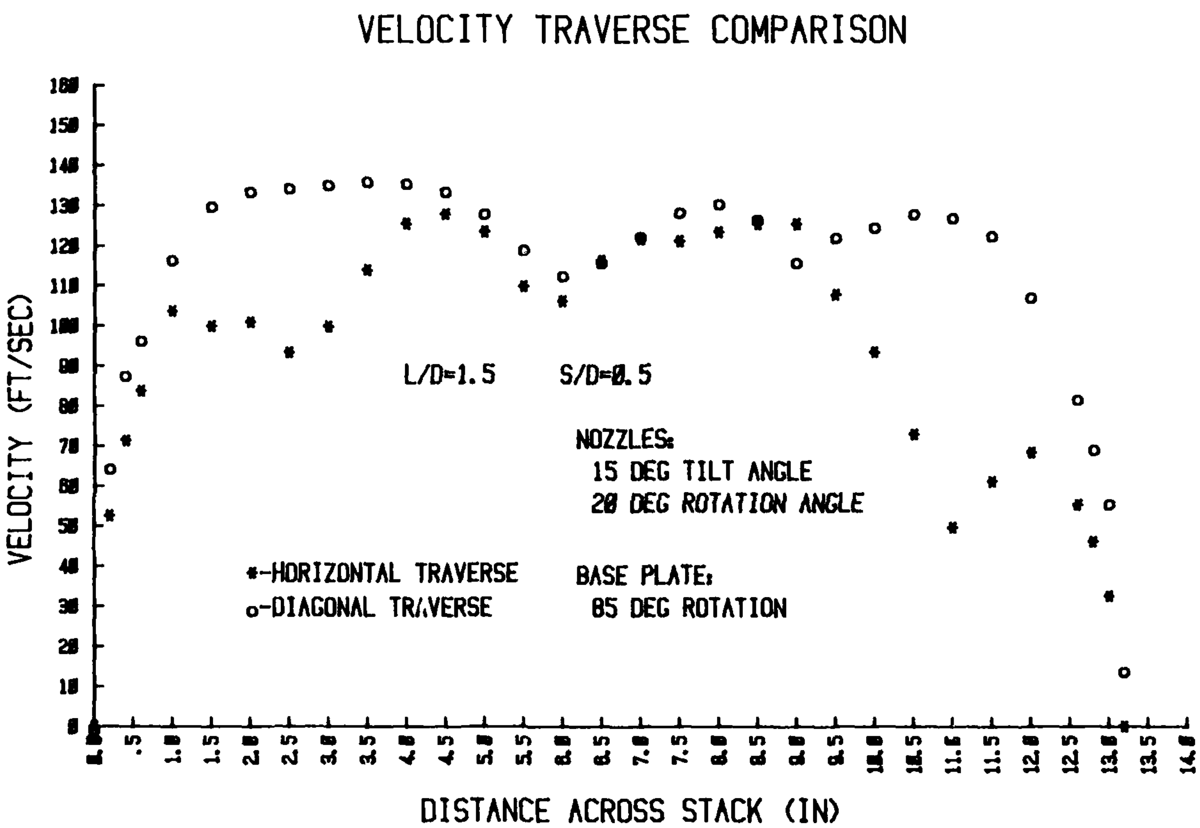



Figure 33. VTD

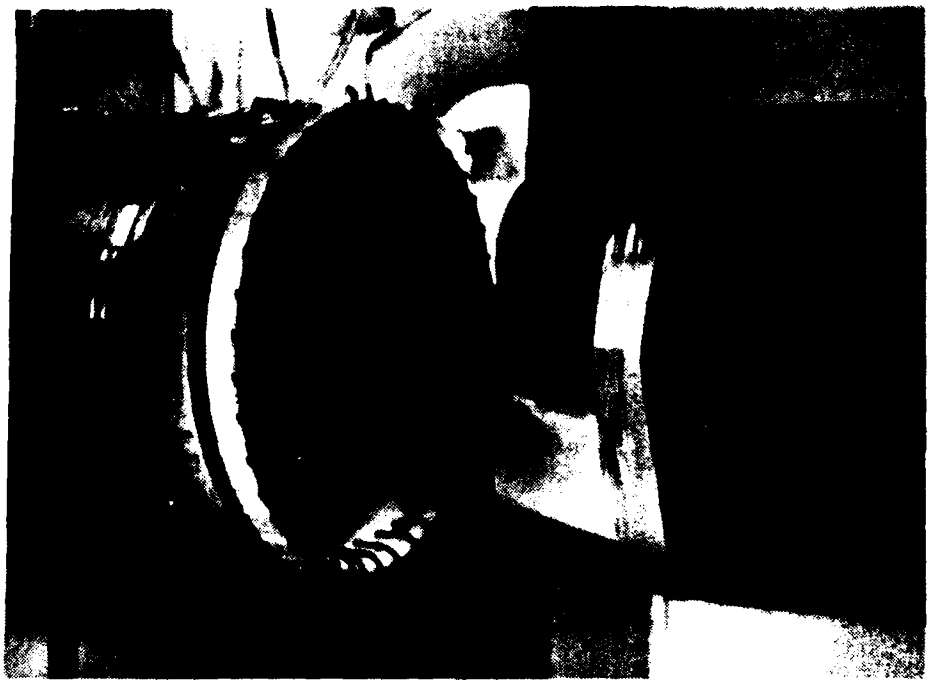


Figure 34. Tufting of Stack Entrance

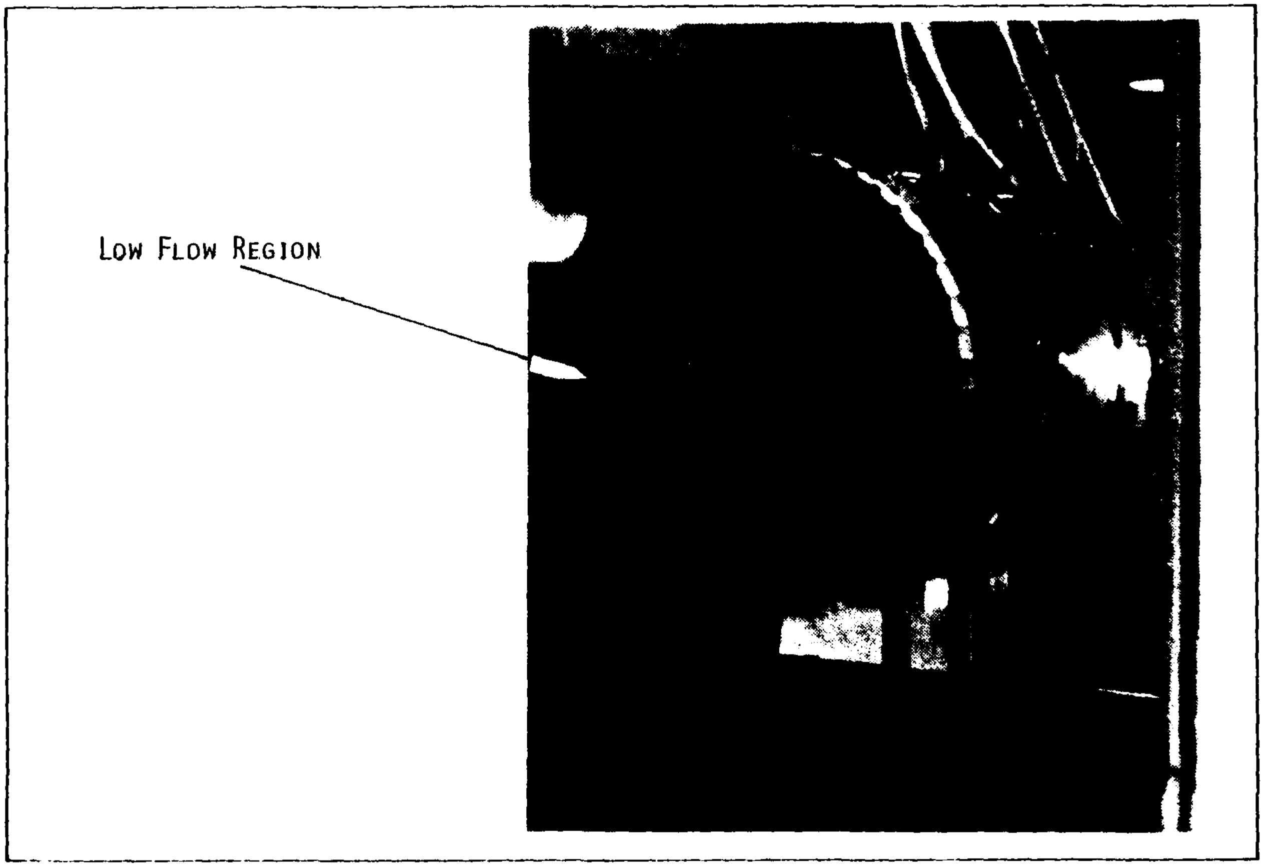



Figure 35. Tufting of Stack Exit

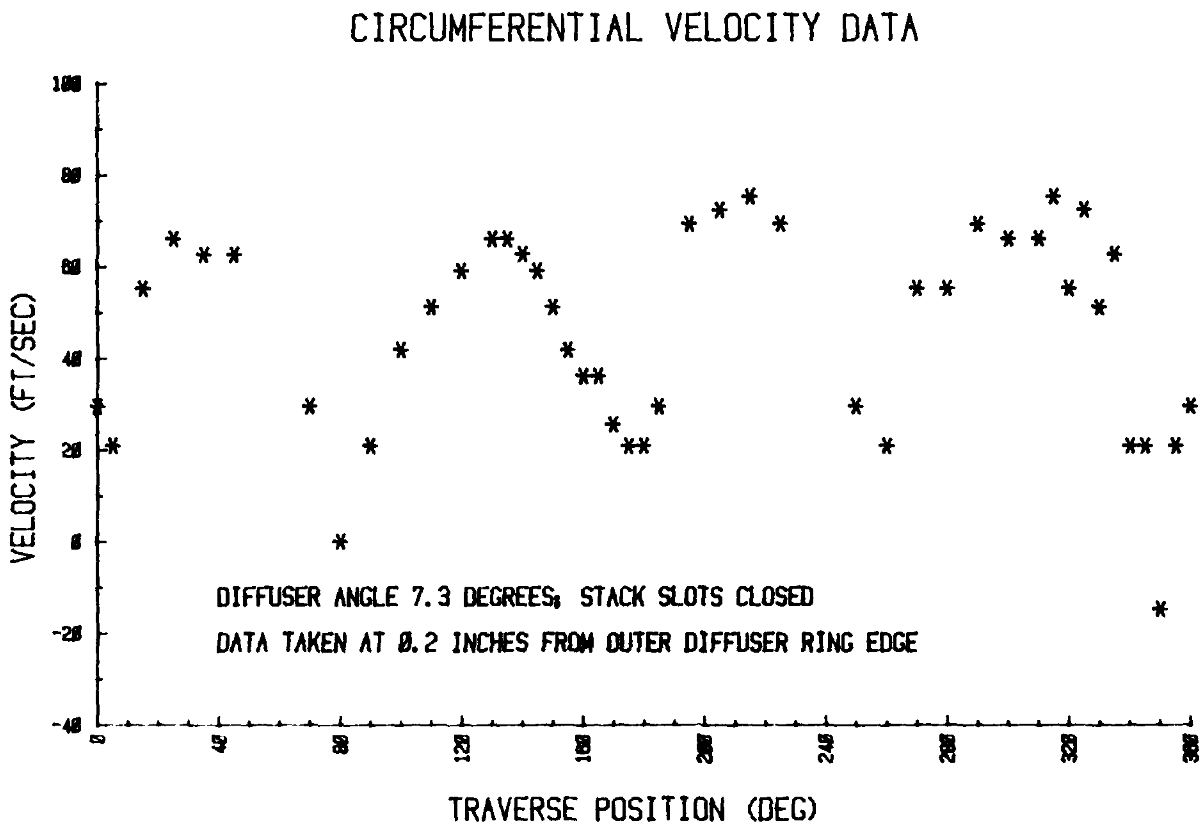



Figure 36. Slots Closed

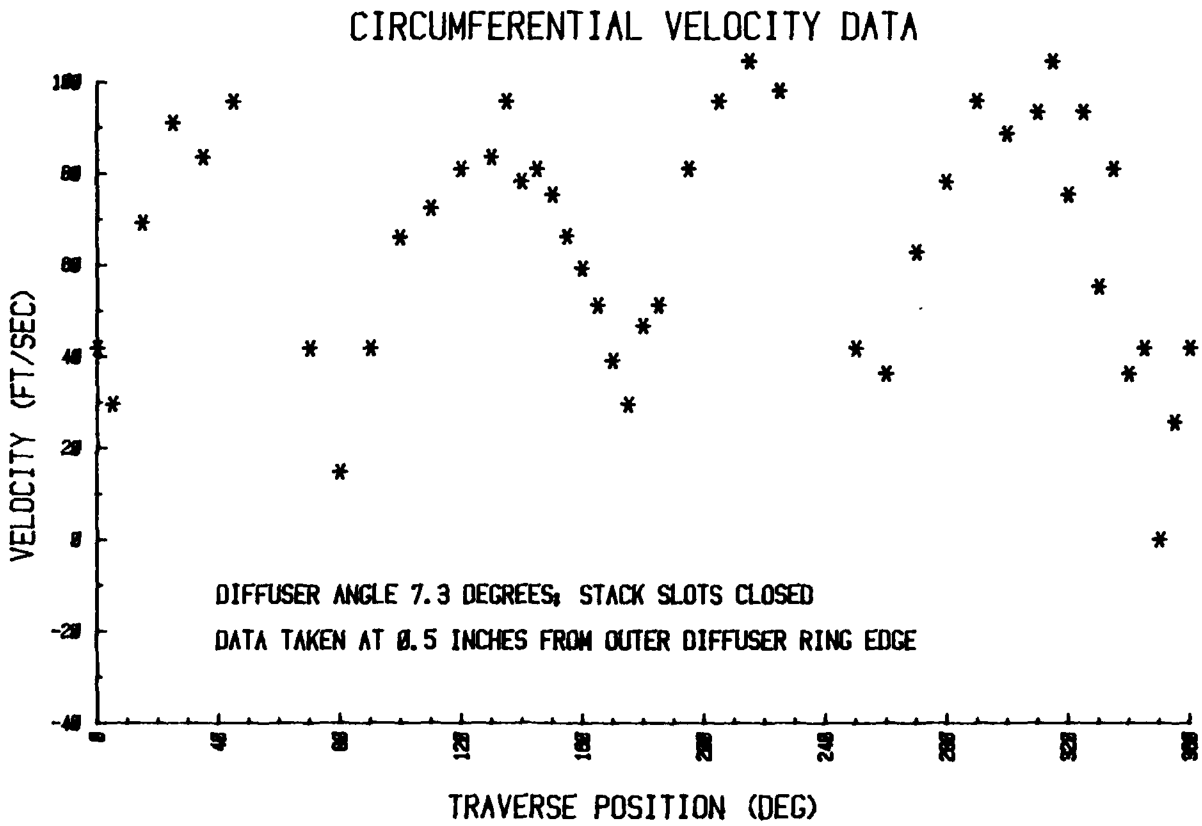

CIRCUMFERENTIAL VELOCITY DATA
VELOCITY (FT/SEC)
100
80
60
40
20
0
-20
-40
DIFFUSER ANGLE 7.3 DEGREES; STACK SLOTS CLOSED
DATA TAKEN AT 0.5 INCHES FROM OUTER DIFFUSER RING EDGE
0
40
80
120
160
200
240
280
320
360
TRAVERSE POSITION (DEG)

Figure 36.

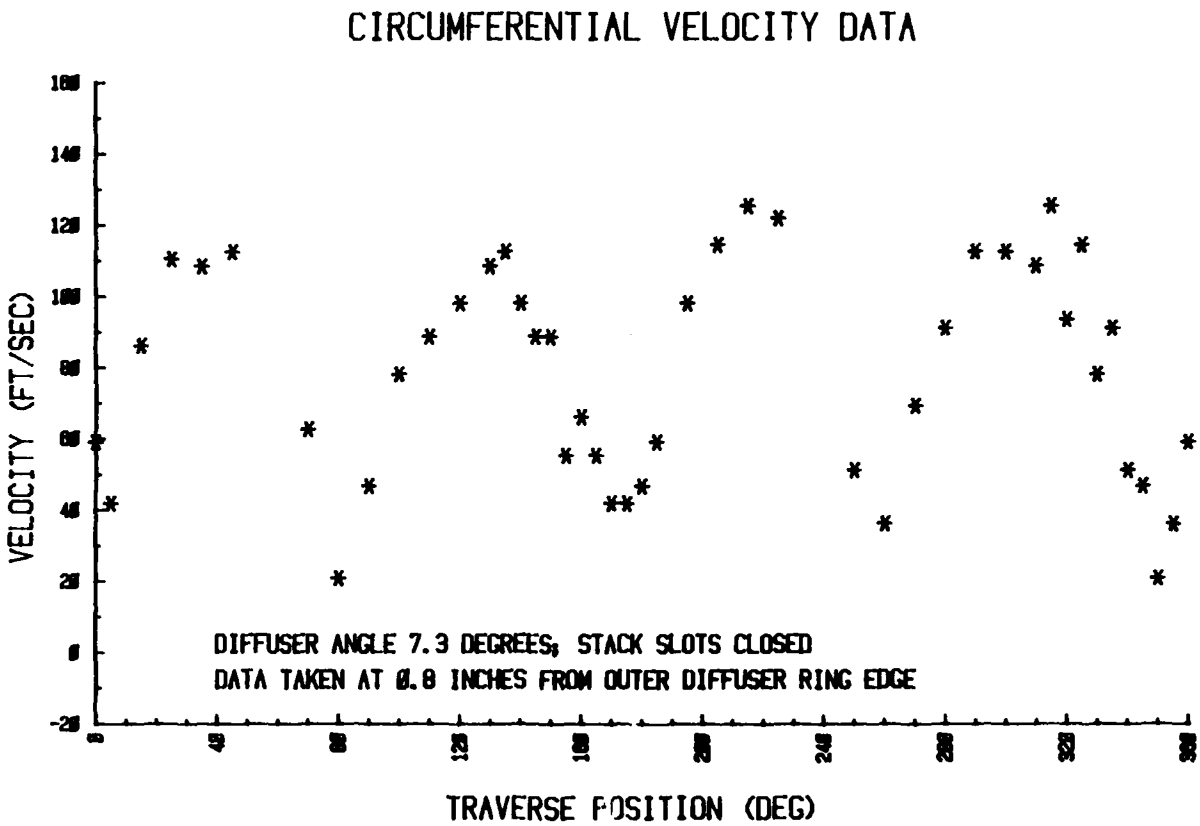

CIRCUMFERENTIAL VELOCITY DATA
VELOCITY (FT/SEC)
TRAVERSE POSITION (DEG)
DIFFUSER ANGLE 7.3 DEGREES; STACK SLOTS CLOSED
DATA TAKEN AT 0.8 INCHES FROM OUTER DIFFUSER RING EDGE

Figure 36.

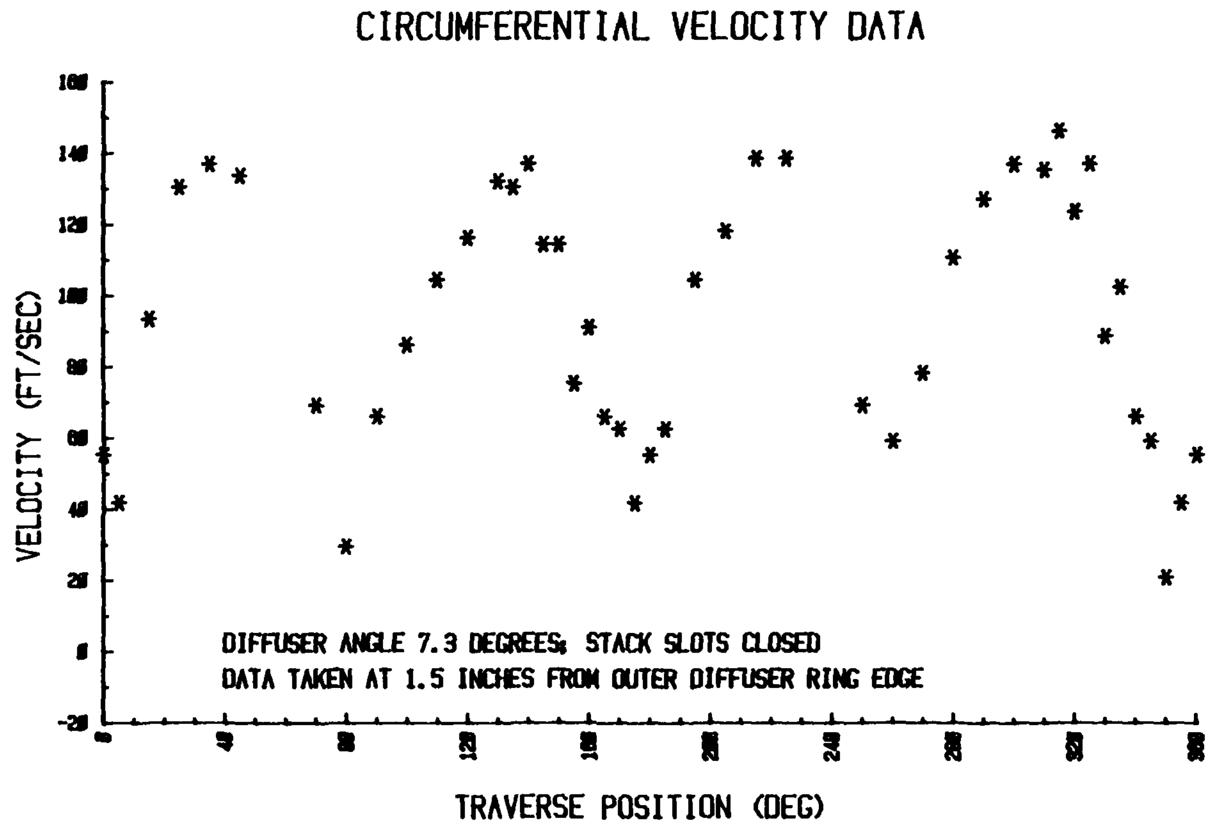

CIRCUMFERENTIAL VELOCITY DATA
VELOCITY (FT/SEC)
TRAVERSE POSITION (DEG)
DIFFUSER ANGLE 7.3 DEGREES; STACK SLOTS CLOSED
DATA TAKEN AT 1.5 INCHES FROM OUTER DIFFUSER RING EDGE

Figure 36.

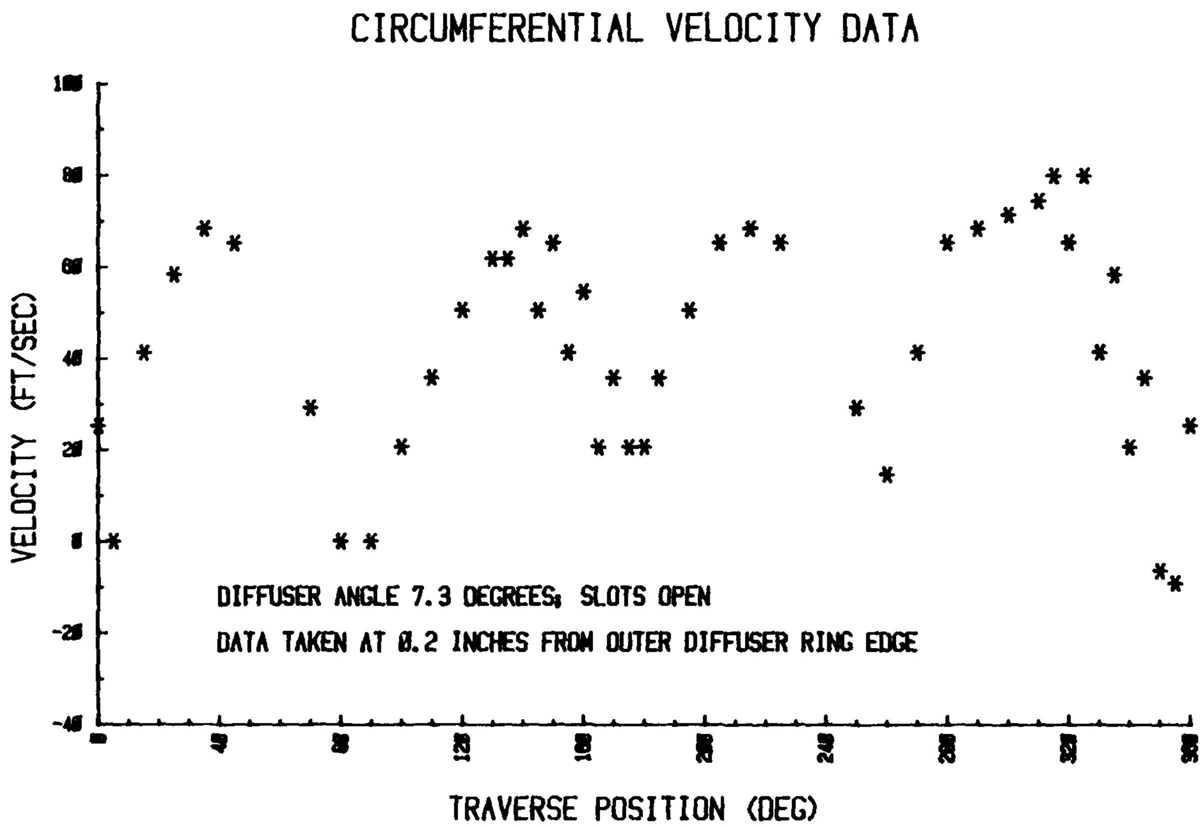



Figure 37. Slots Open

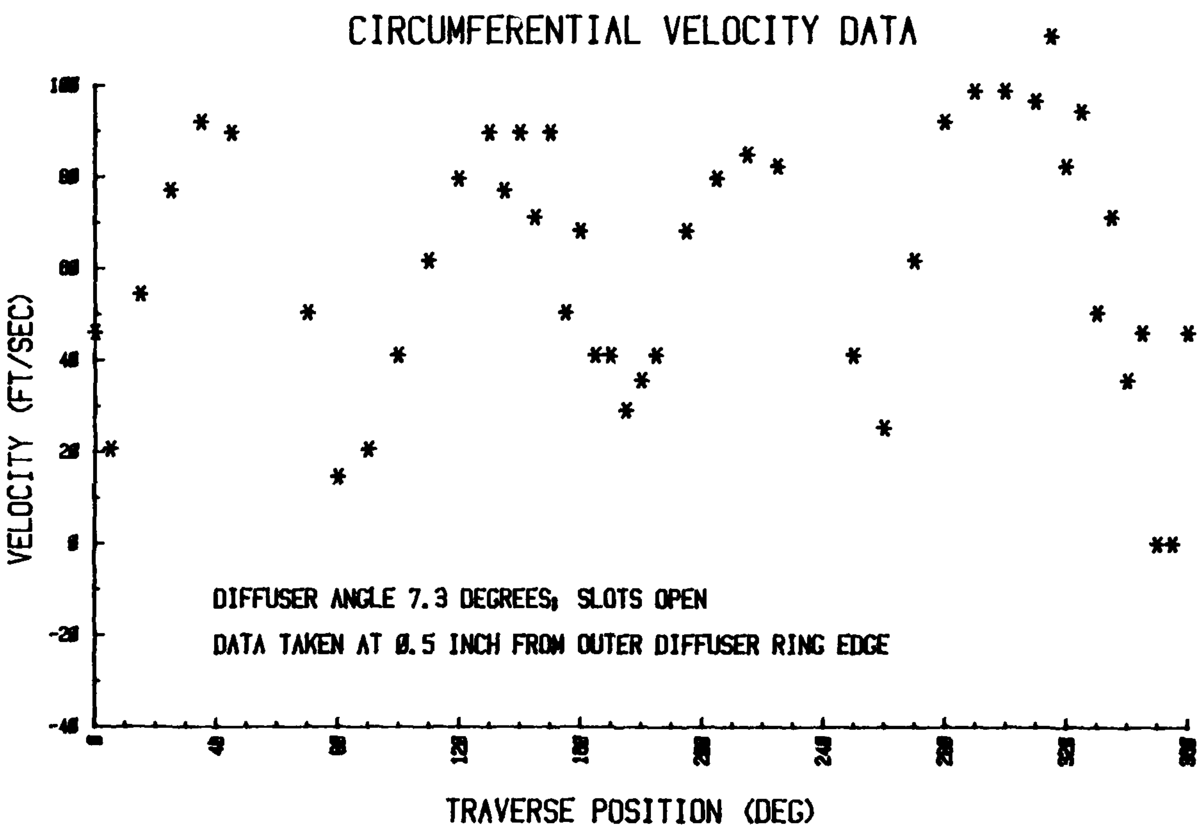
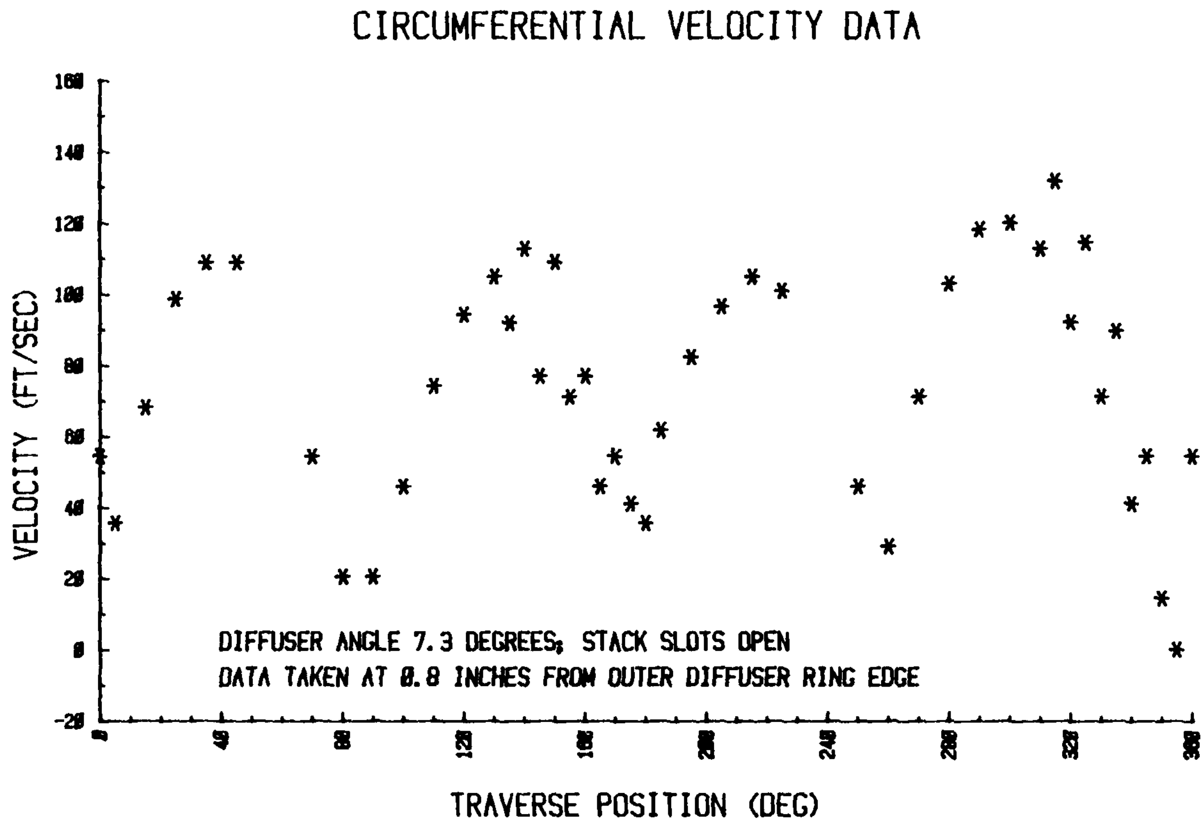

CIRCUMFERENTIAL VELOCITY DATA
VELOCITY (FT/SEC)
TRAVERSE POSITION (DEG)
DIFFUSER ANGLE 7.3 DEGREES; SLOTS OPEN
DATA TAKEN AT Ø.5 INCH FROM OUTER DIFFUSER RING EDGE

Figure 37.



CIRCUMFERENTIAL VELOCITY DATA
VELOCITY (FT/SEC)
160
140
120
100
80
60
40
20
0
-20
0
40
80
120
160
200
240
280
320
360
TRAVERSE POSITION (DEG)
DIFFUSER ANGLE 7.3 DEGREES; STACK SLOTS OPEN
DATA TAKEN AT 0.8 INCHES FROM OUTER DIFFUSER RING EDGE

Figure 37.

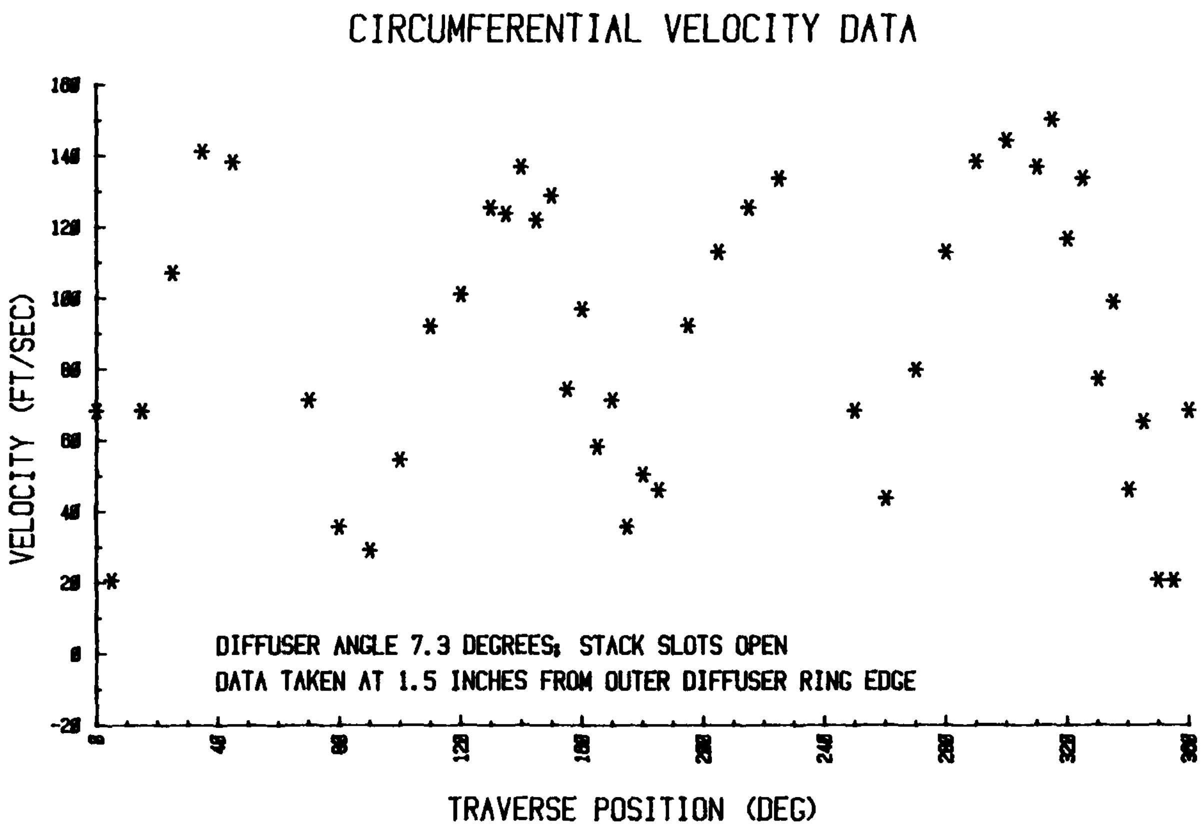

CIRCUMFERENTIAL VELOCITY DATA
VELOCITY (FT/SEC)
TRAVERSE POSITION (DEG)
DIFFUSER ANGLE 7.3 DEGREES; STACK SLOTS OPEN
DATA TAKEN AT 1.5 INCHES FROM OUTER DIFFUSER RING EDGE
160
140
120
100
80
60
40
20
0
-20
0
40
80
120
160
200
240
280
320
360

Figure 37.

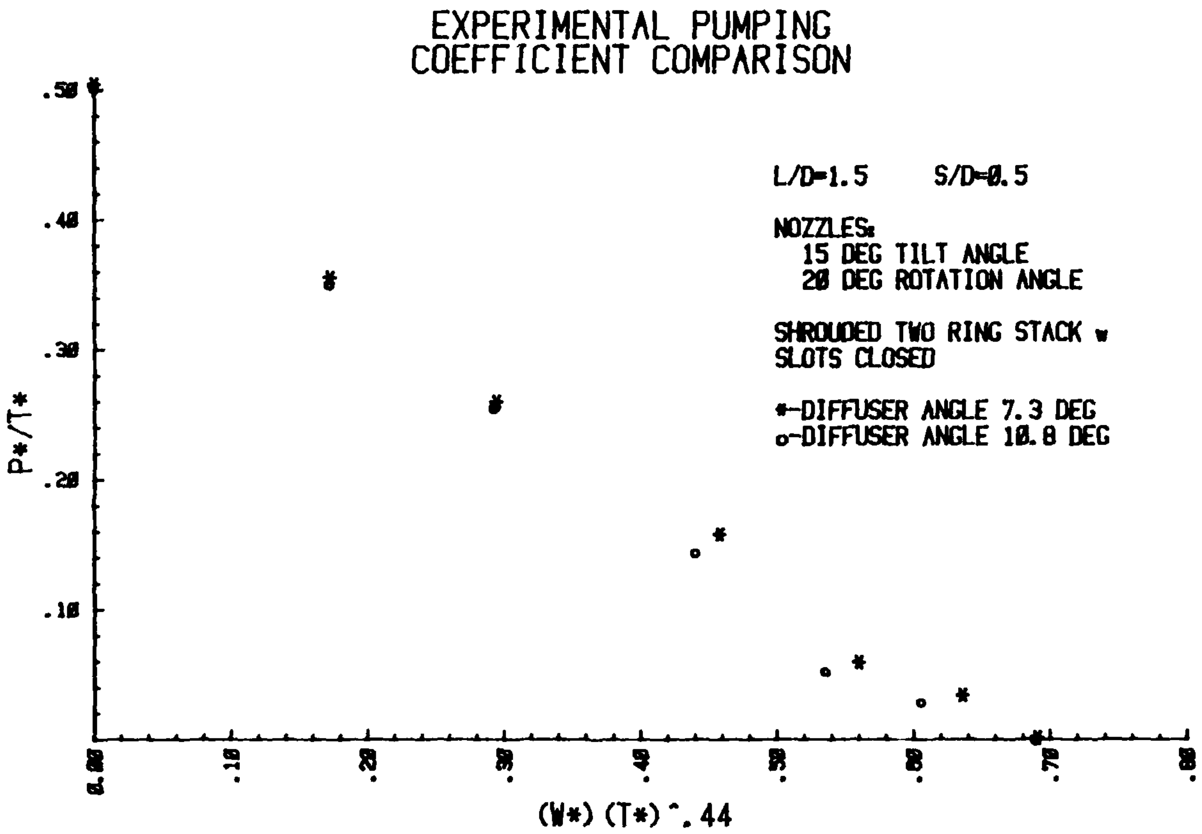



Figure 38. Slots Closed

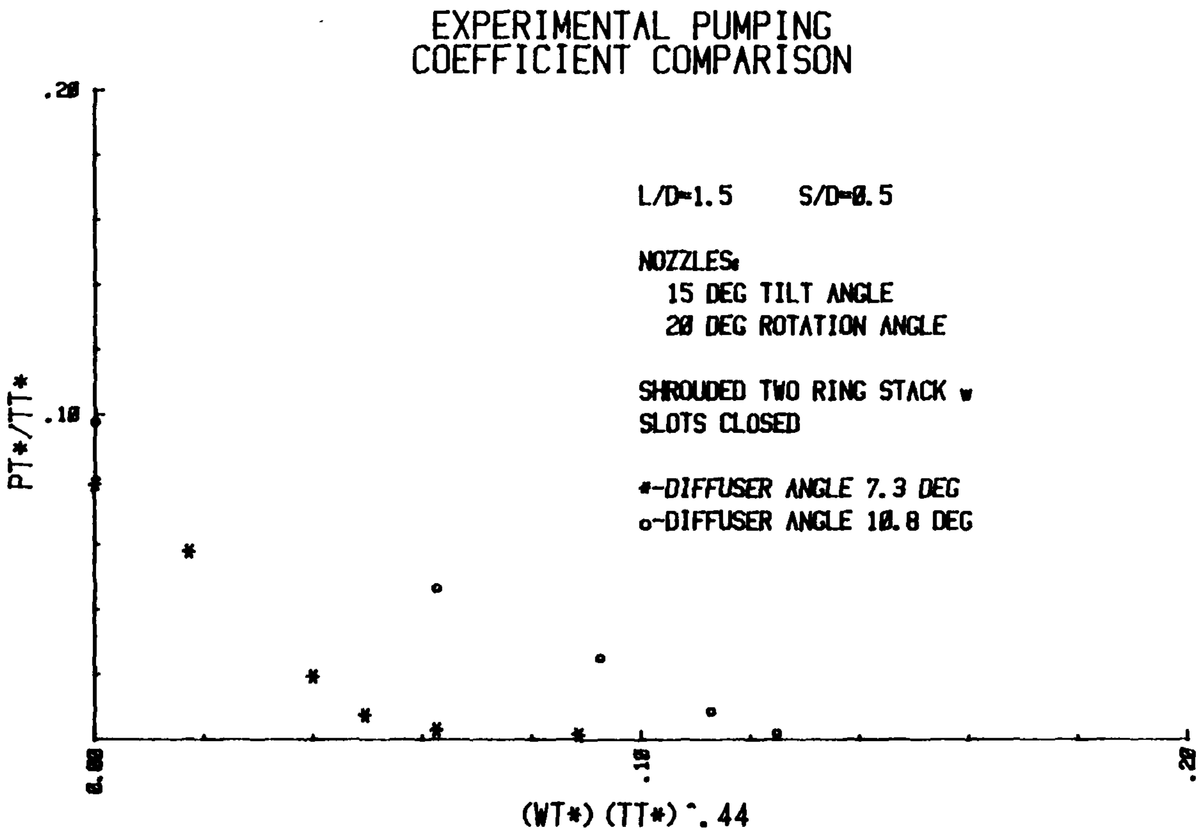



Figure 38. PCD

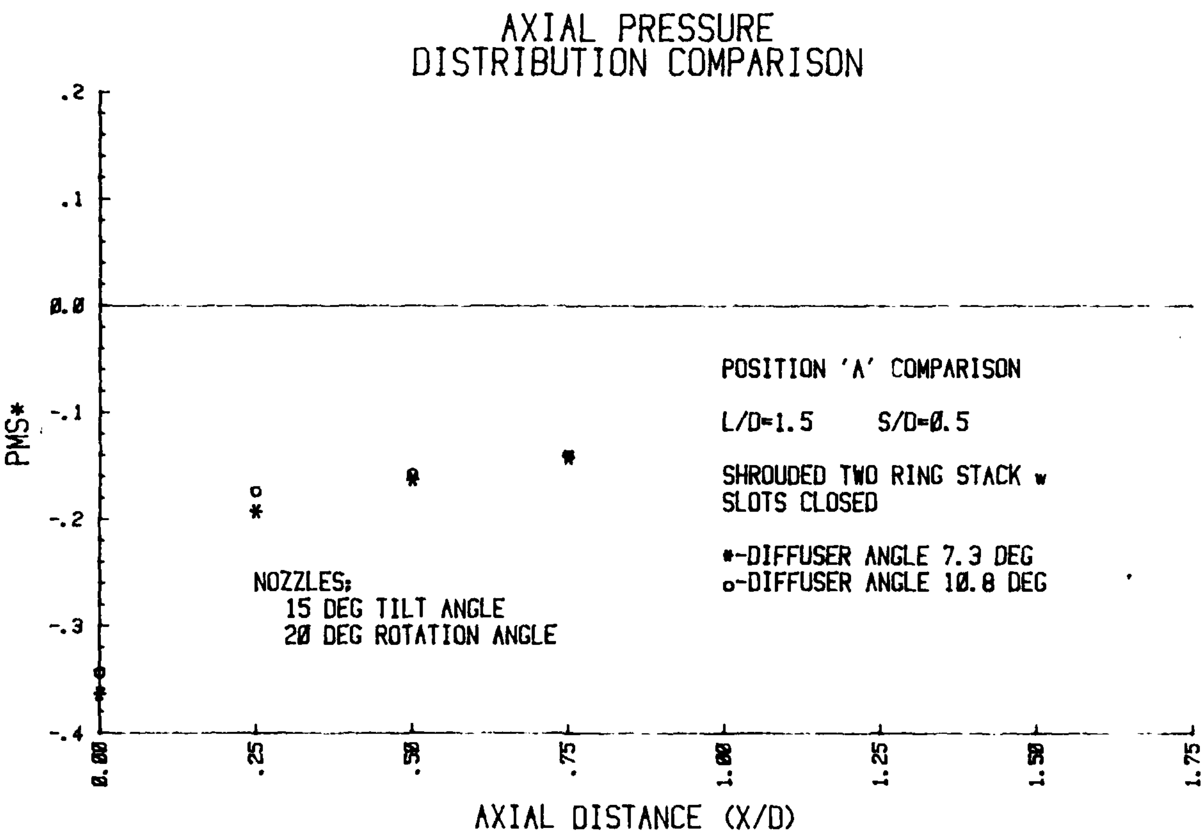



Figure 38. MSD

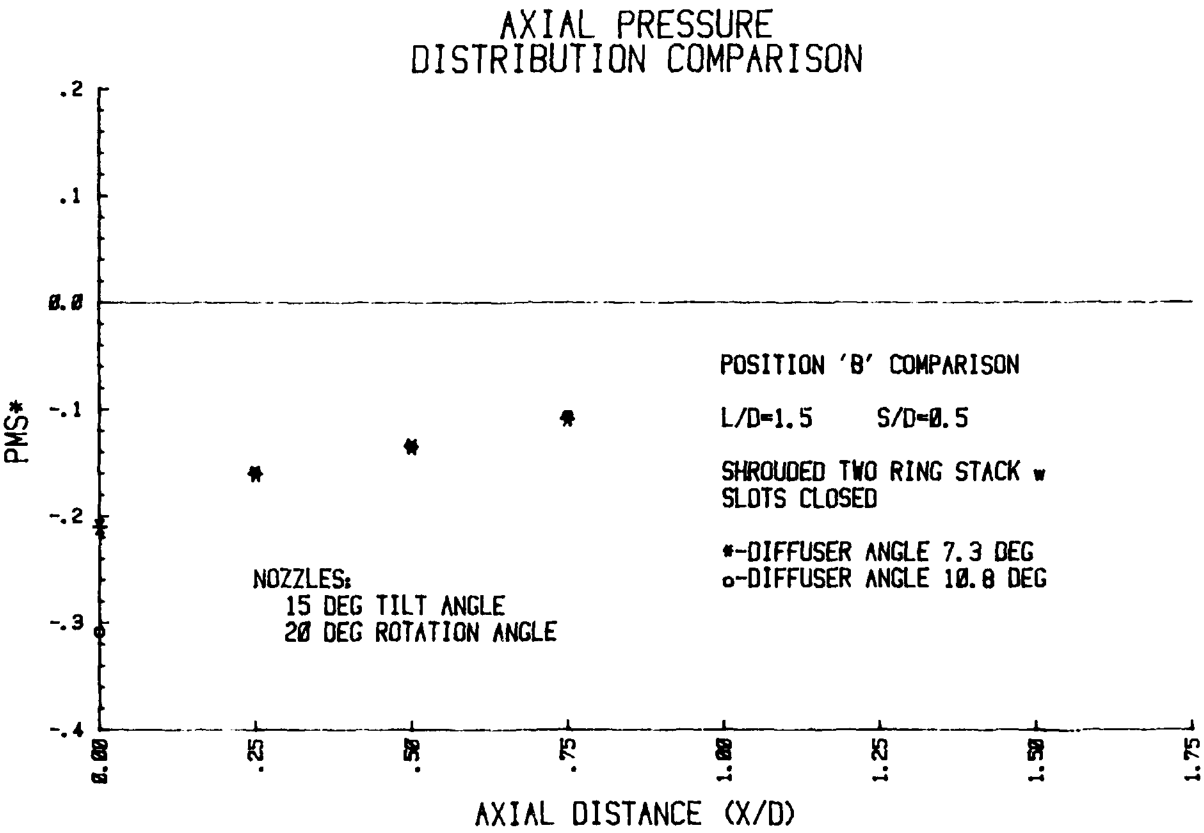
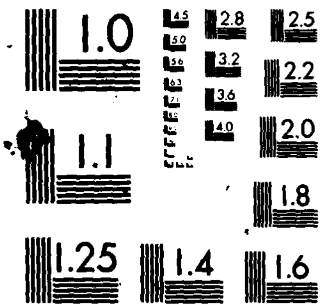



Figure 38. MSD

AD-A116 304 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 21/5
CHARACTERISTICS OF A FOUR-NOZZLE, SLOTTED SHORT MIXING STACK WI--ETC(U)
MAR 82 C J DRUCKER
UNCLASSIFIED NL

3 of 3

END
DATE
FILMED
7 82
DTIC




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

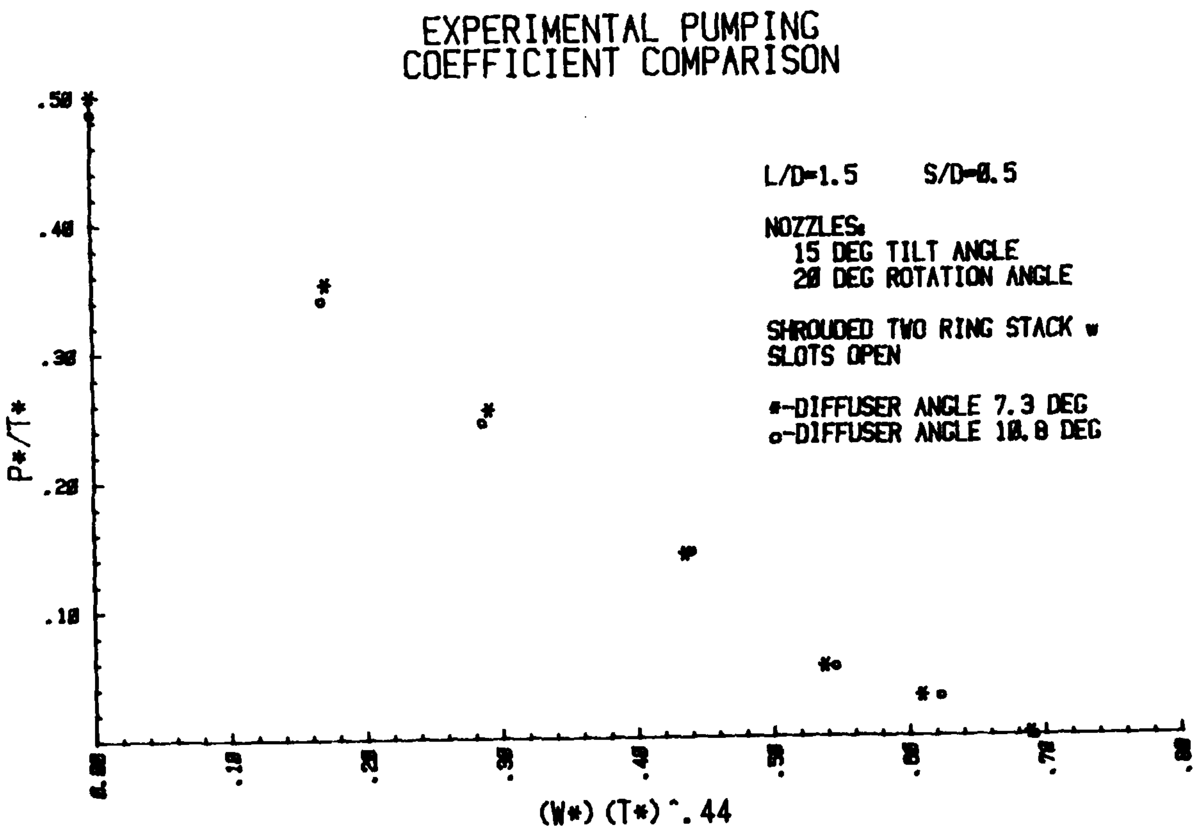



Figure 39. Slots Open

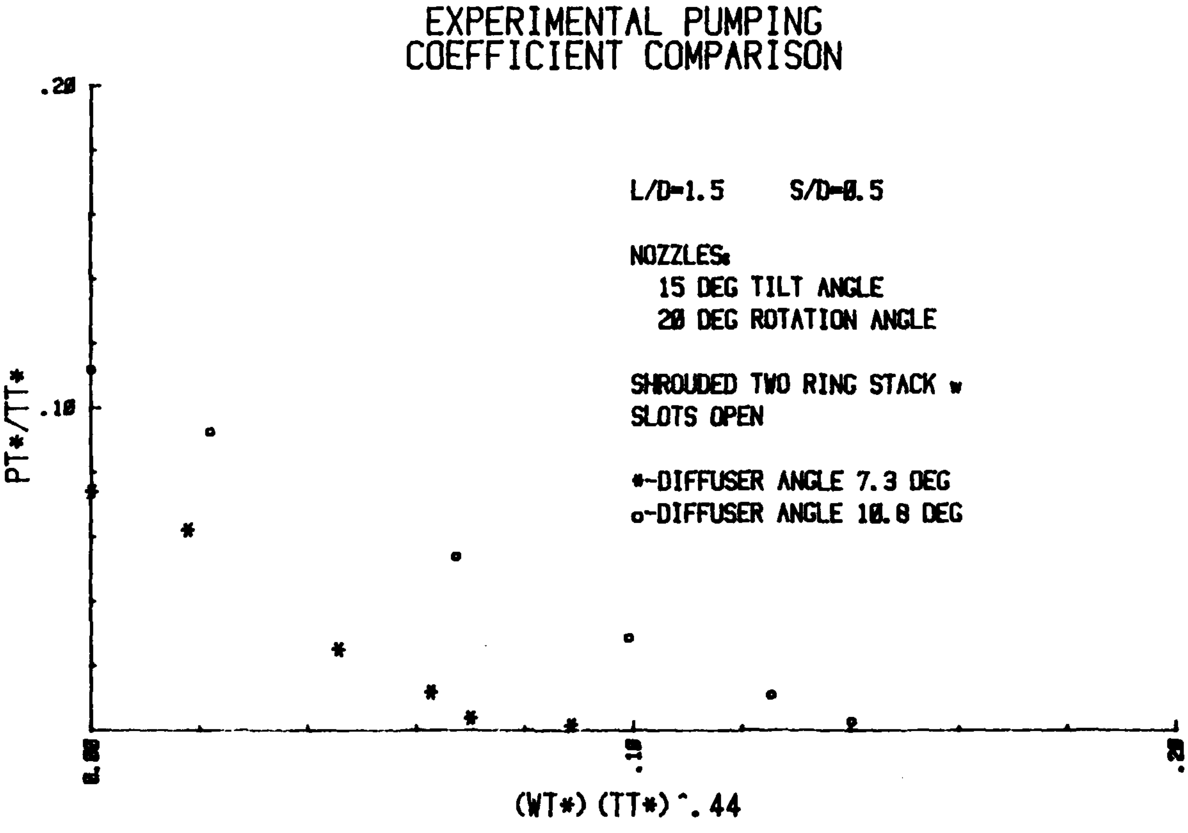



Figure 39. PCD

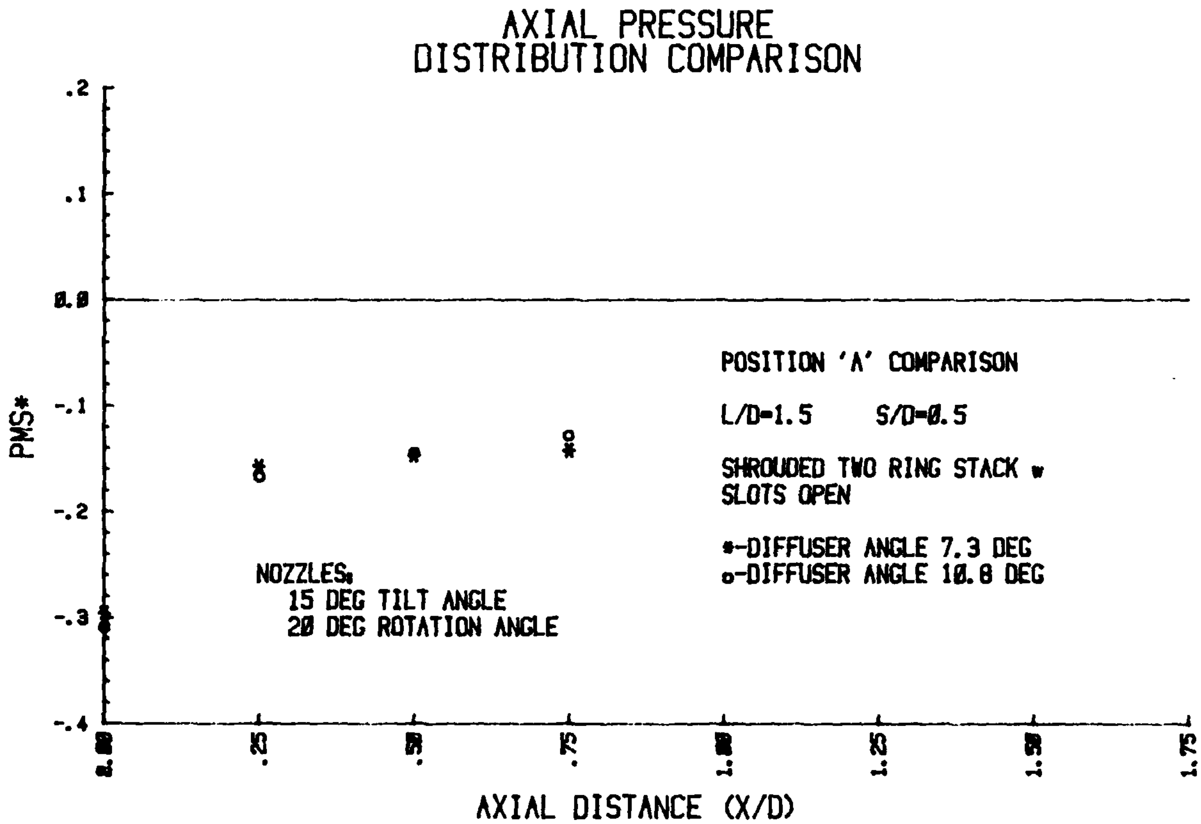



Figure 39. MSD

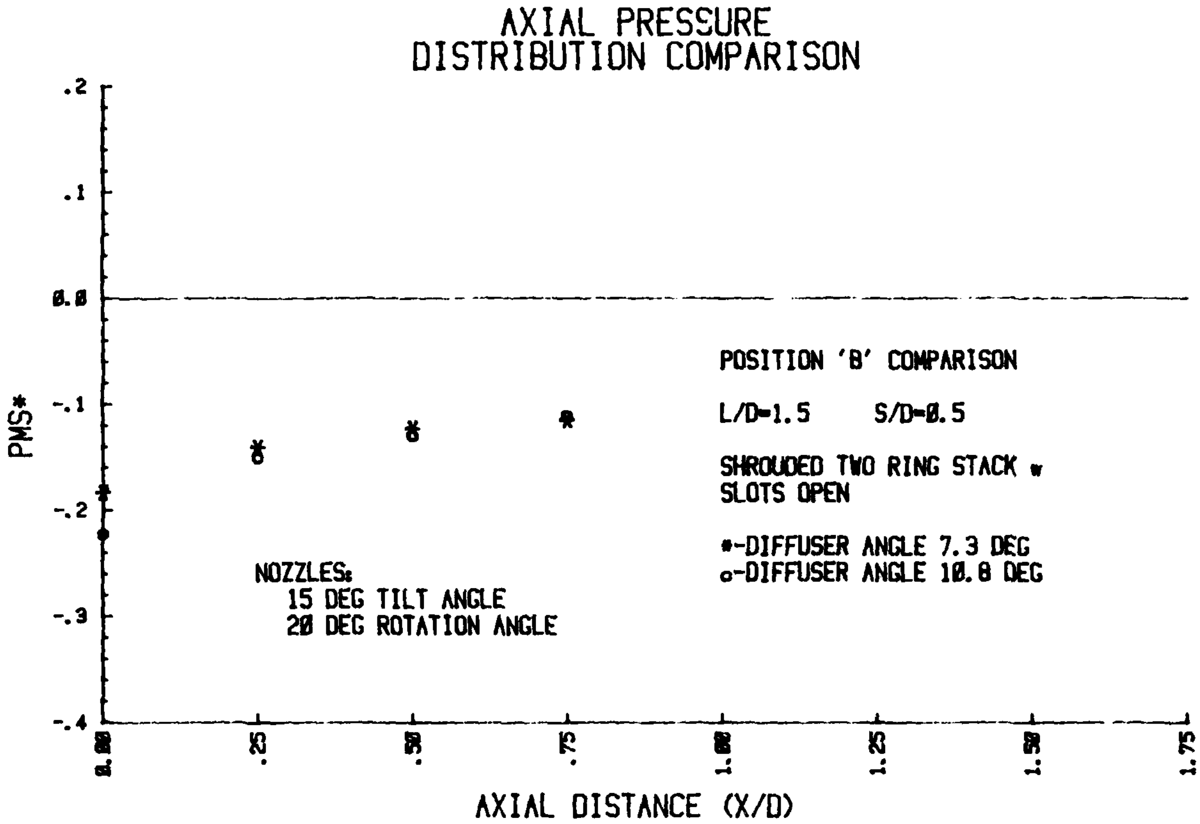



Figure 39. MSD

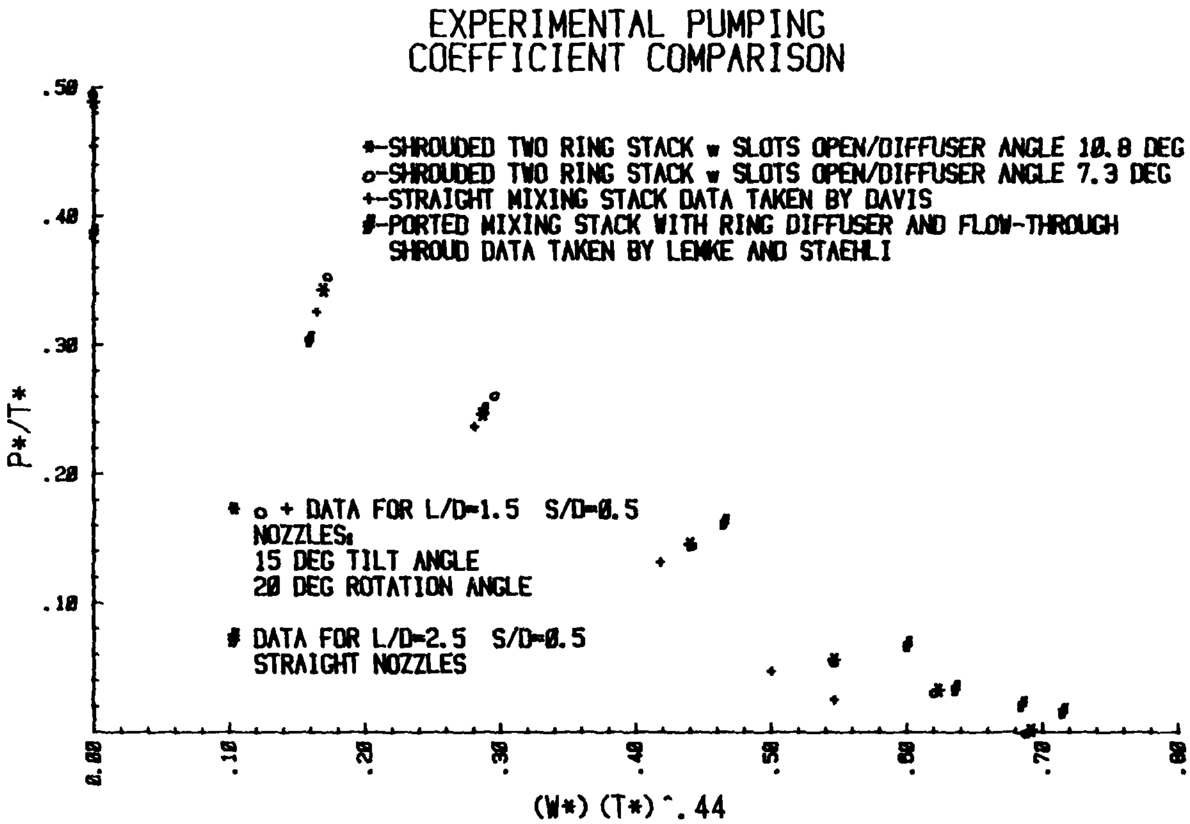



Figure 39. PCD

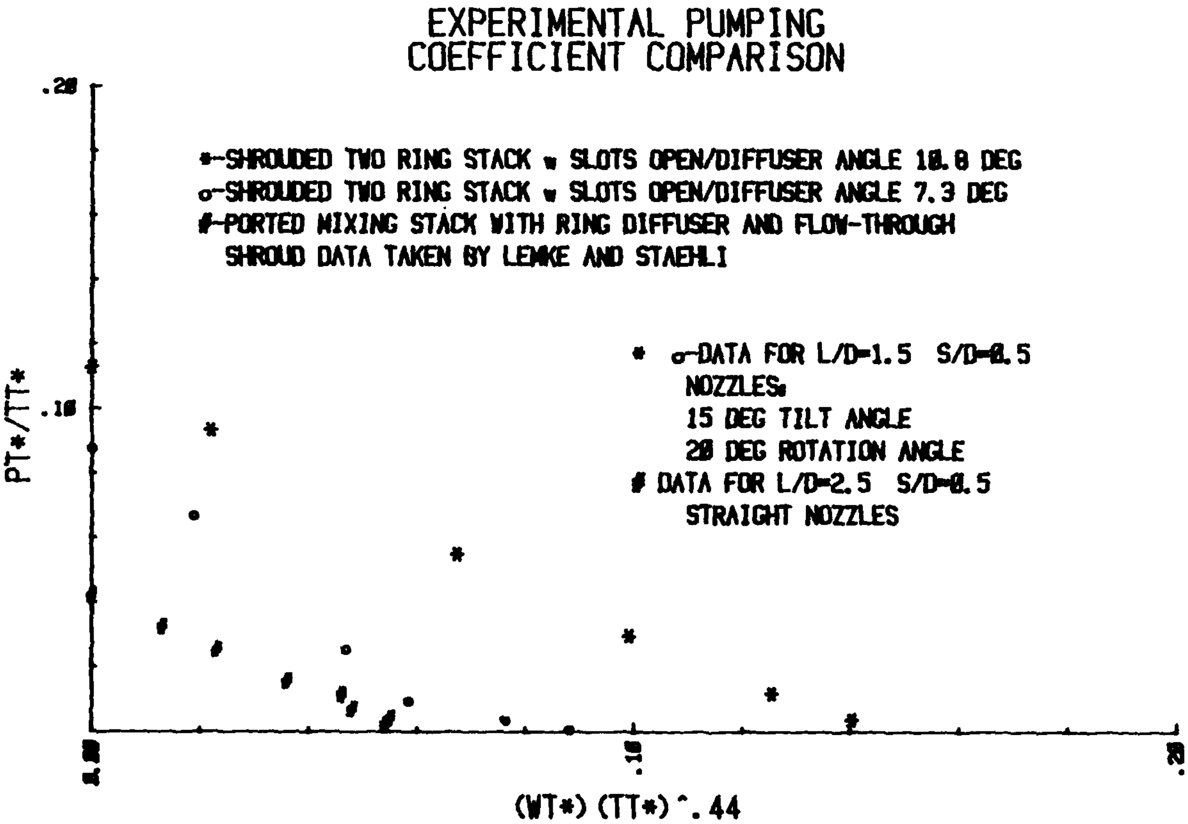



Figure 39. PCD

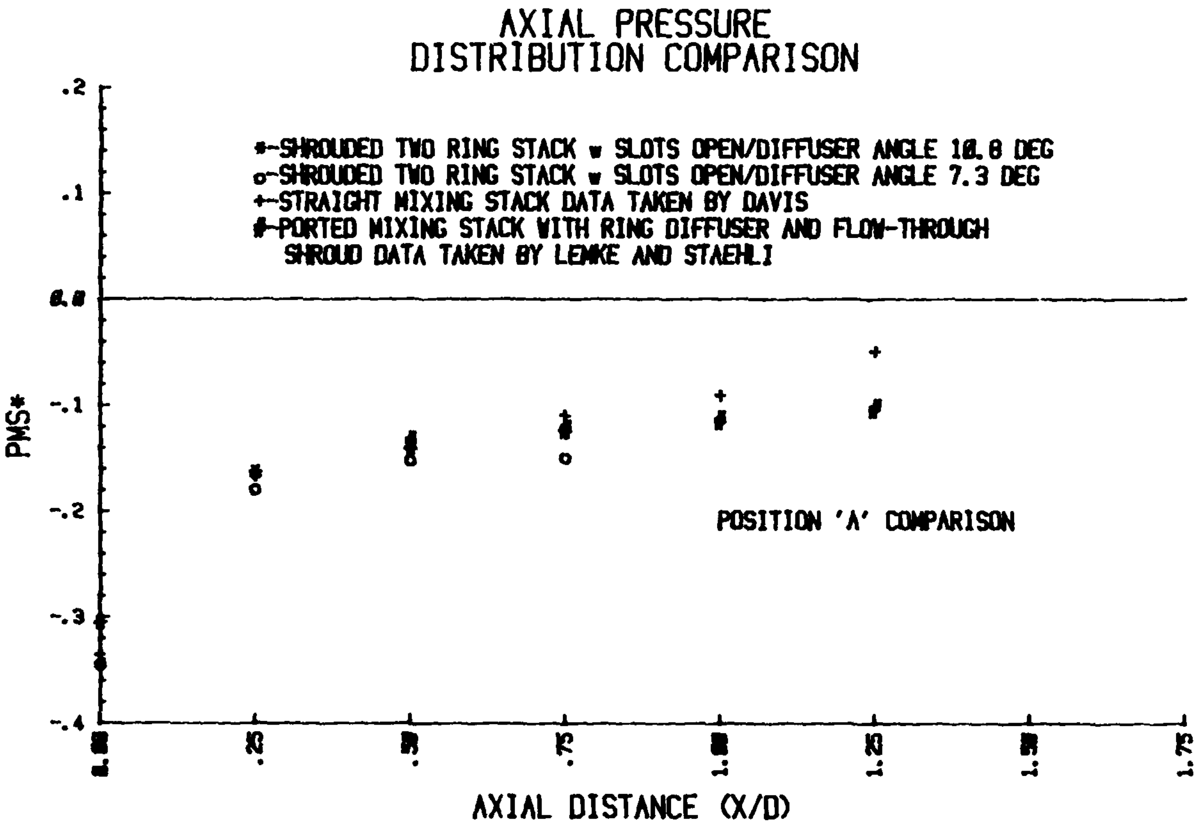



Figure 39. MSD

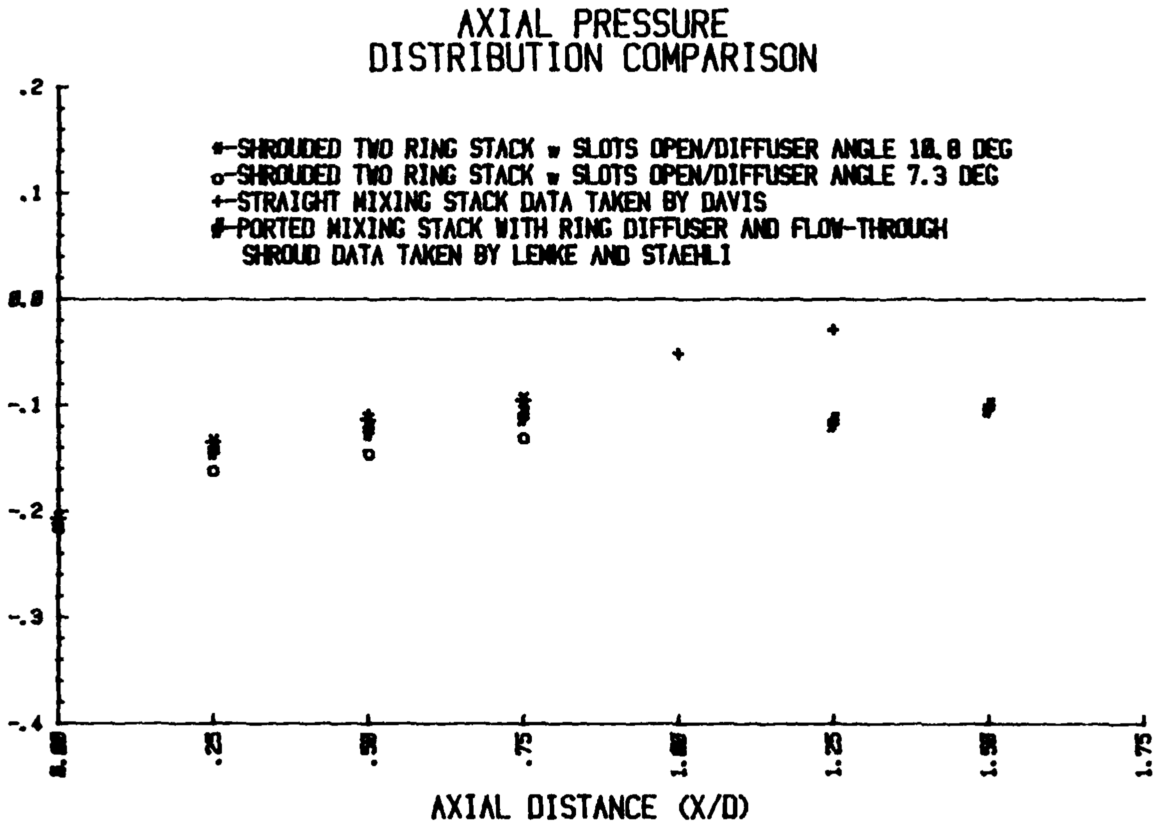



Figure 39. MSD

DATA TAKEN ON: 27 SEP 81
DATA TAKEN BY: DRUCKER/DAVIS          NOZZLE AM/AP AREA RATIO: 2.50

COMMENTS:
15/10-FULL DATA RUN

MIXING STACK INFORMATION:
- LENGTH: 14.63 [IN]
- DIAMETER: 11.70 [IN]
- L/D RATIO: 1.25
- S/D RATIO: 0.50

PRIMARY NOZZLE INFORMATION:
- TILT ANGLE: 15.0 [DEG]
- ROTATION ANGLE: 10 [DEG]
- AREA PER NOZZLE: 10.752 [IN2]
- NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION:
- ORIFICE DIAMETER: 6.902 [IN]
- ORIFICE BETA: 0.497
- UPTAKE AREA: 107.510 [IN2]
- ATM. PRESSURE: 30.12 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0.705 | 22.2 | 60.0 | 114.8 | 73.0 | 3.50 | 3.05 | 0.00 | 0.000 | ******* |
| 2 | 0.705 | 22.0 | 61.0 | 115.2 | 73.4 | 4.26 | 2.10 | 0.00 | 12.566 | ******* |
| 3 | 0.700 | 21.9 | 61.2 | 115.4 | 73.6 | 4.85 | 1.56 | 0.00 | 25.133 | ******* |
| 4 | 0.710 | 22.3 | 61.2 | 115.0 | 74.0 | 5.55 | 0.00 | 0.00 | 50.265 | ******* |
| 5 | 0.705 | 22.2 | 61.6 | 115.6 | 74.2 | 6.05 | 0.33 | 0.00 | 100.531 | ******* |
| 6 | 0.705 | 22.1 | 61.4 | 115.8 | 74.2 | 6.20 | 0.18 | 0.00 | 150.796 | ******* |
| 7 | 0.700 | 22.1 | 61.4 | 115.0 | 74.4 | 6.40 | 0.01 | 0.00 | ******* | ******* |

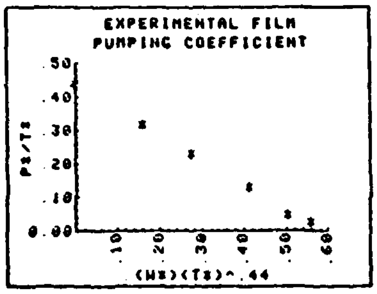
SECONDARY BOX

| N | W* | P* | T* | P*/T* W*T^.44 | | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0.0000 | 0.4087 | 0.9272 | 0.4408 | 0.0000 | 3.7616 | 0.0000 | 102.52 | 73.01 | 73.01 | 0.062 |
| 2 | 0.1689 | 0.2960 | 0.9273 | 0.3192 | 0.1634 | 3.7439 | 0.6323 | 101.40 | 83.07 | 72.57 | 0.062 |
| 3 | 0.2864 | 0.2134 | 0.9273 | 0.2302 | 0.2771 | 3.7346 | 1.0696 | 100.74 | 91.43 | 72.30 | 0.062 |
| 4 | 0.4262 | 0.1186 | 0.9274 | 0.1278 | 0.4123 | 3.7686 | 1.6061 | 102.20 | 101.63 | 72.89 | 0.062 |
| 5 | 0.5232 | 0.0449 | 0.9280 | 0.0483 | 0.5063 | 3.7507 | 1.9667 | 101.42 | 107.70 | 72.57 | 0.062 |
| 6 | 0.5809 | 0.0246 | 0.9277 | 0.0265 | 0.5620 | 3.7509 | 2.1707 | 101.04 | 111.43 | 72.42 | 0.062 |
| 7 | ****** | 0.0014 | 0.9201 | 0.0015 | ****** | 3.7509 | 2.6720 | 100.97 | ****** | 72.39 | 0.062 |

Table 1. 15/10 Nozzles: Straight Stack L/D=1.25

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | WM LBM SEC | WT LBM SEC | UE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | ****** | 0.0000 | 0.9272 | 0.0000 | ******* | 3.762 | ******* | ****** |
| 2 | ****** | 0.0000 | 0.9273 | 0.0000 | ******* | 4.376 | ******* | ****** |
| 3 | ****** | 0.0000 | 0.9273 | 0.0000 | ******* | 4.004 | ******* | ****** |
| 4 | ****** | 0.0000 | 0.9274 | 0.0000 | ******* | 5.375 | ******* | ****** |
| 5 | ****** | 0.0000 | 0.9280 | 0.0000 | ******* | 5.725 | ******* | ****** |
| 6 | ****** | 0.0000 | 0.9277 | 0.0000 | ******* | 5.930 | ******* | ****** |
| 7 | ****** | 0.0000 | 0.9281 | 0.0000 | ******* | ****** | ******* | ****** |



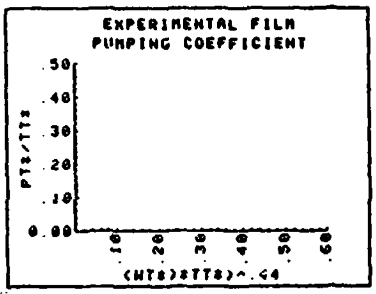
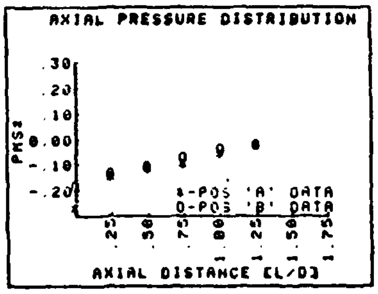




Table 1.  PCD (cont)

MIXING STACK DATA FOR RUN 7

| TOP (POSITION 'A') DATA | | | | DIAGONAL (POSITION 'B') DATA | | | |
|---|---|---|---|---|---|---|---|
| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* | X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
| 0.00 | -1.900 | 86 | -0.271 | 0.00 | -1.360 | 86 | -0.186 |
| 0.25 | -1.050 | 24 | -0.144 | 0.25 | -0.960 | 24 | -0.131 |
| 0.50 | -0.790 | 23 | -0.108 | 0.50 | -0.770 | 23 | -0.105 |
| 0.75 | -0.690 | 14 | -0.094 | 0.75 | -0.530 | 14 | -0.072 |
| 1.00 | -0.390 | 4 | -0.053 | 1.00 | -0.260 | 4 | -0.036 |
| 1.25 | -0.150 | 1 | -0.021 | 1.25 | -0.120 | 1 | -0.016 |



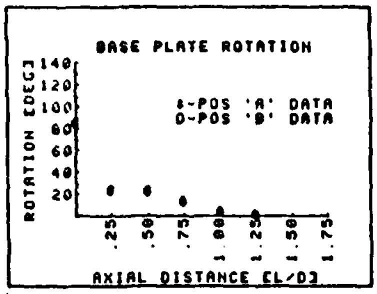
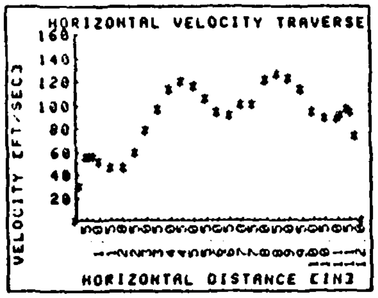




Table 1. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 09 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O] | 0.00 | 0.20 | 0.70 | 0.70 | 0.70 | 0.60 | 0.50 |
| V[FT/SEC] | 0.00 | 29.92 | 55.97 | 55.97 | 55.97 | 51.82 | 47.31 |
| POSIT[IN] | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O] | 0.50 | 0.80 | 1.40 | 2.10 | 2.90 | 3.20 | 3.00 |
| V[FT/SEC] | 47.31 | 59.84 | 79.16 | 96.95 | 113.93 | 119.68 | 115.88 |
| POSIT[IN] | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O] | 2.50 | 2.00 | 1.90 | 2.30 | 2.30 | 3.30 | 3.60 |
| V[FT/SEC] | 105.78 | 94.61 | 92.22 | 101.46 | 101.46 | 121.53 | 126.94 |
| POSIT[IN] | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O] | 3.40 | 2.90 | 2.00 | 1.80 | 1.80 | 1.90 | 2.10 |
| V[FT/SEC] | 123.36 | 113.93 | 94.61 | 89.76 | 89.76 | 92.22 | 96.95 |
| POSIT[IN] | 11.60 | 11.80 | 12.00 | | | | |
| P[IN H2O] | 2.00 | 1.20 | 0.00 | | | | |
| V[FT/SEC] | 94.61 | 73.29 | 0.00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 09 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O] | 0.00 | 1.50 | 2.60 | 3.10 | 3.40 | 4.00 | 5.10 |
| V[FT/SEC] | 0.00 | 81.94 | 107.88 | 117.79 | 123.36 | 133.80 | 151.09 |
| POSIT[IN] | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O] | 5.50 | 5.00 | 4.10 | 3.30 | 2.80 | 2.90 | 2.80 |
| V[FT/SEC] | 156.90 | 149.60 | 135.47 | 121.53 | 111.95 | 113.93 | 111.95 |
| POSIT[IN] | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O] | 2.30 | 1.90 | 1.90 | 2.40 | 2.70 | 2.60 | 2.40 |
| V[FT/SEC] | 101.46 | 92.22 | 92.22 | 103.64 | 109.93 | 107.88 | 103.64 |
| POSIT[IN] | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O] | 2.30 | 2.70 | 3.40 | 4.40 | 5.20 | 5.40 | 5.30 |
| V[FT/SEC] | 101.46 | 109.93 | 123.36 | 140.34 | 152.56 | 155.47 | 154.02 |
| POSIT[IN] | 11.60 | 11.80 | 12.00 | | | | |
| P[IN H2O] | 4.90 | 3.30 | 0.00 | | | | |
| V[FT/SEC] | 140.09 | 121.53 | 0.00 | | | | |

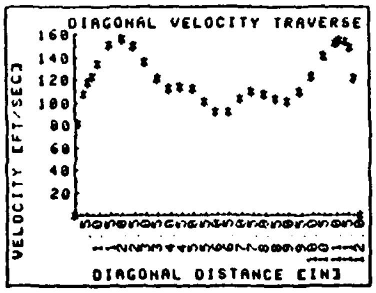



Table 1. VTD

DATA TAKEN ON: 29 SEP 81
DATA TAKEN BY: DRUCKER

NOZZLE AM/AP AREA RATIO: 2.50

COMMENTS:
OFF SPEED PERFORMANCE 15/20 NOZ

MIXING STACK INFORMATION
LENGTH 14.63 [IN]
DIAMETER: 11.70 [IN]
L/D RATIO: 1.25
S/D RATIO: 0.50

PRIMARY NOZZLE INFORMATION:
TILT ANGLE 15.0 [DEG]
ROTATION ANGLE: 20 [DEG]
AREA PER NOZZLE: 10.752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION:
ORIFICE DIAMETER: 6.902 [IN]
ORIFICE BETA: 0.457
UPTAKE AREA: 107.510 [IN2]
ATM. PRESSURE: 30.03 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0.200 | 5.5 | 58.6 | 115.2 | 70.4 | 0.90 | 0.78 | 0.00 | 0.000 | ******* |
| 2 | 0.195 | 5.5 | 58.8 | 116.4 | 70.6 | 1.10 | 0.56 | 0.00 | 12.566 | ******* |
| 3 | 0.195 | 5.4 | 58.8 | 117.8 | 70.4 | 1.25 | 0.40 | 0.60 | 25.133 | ******* |
| 4 | 0.200 | 5.6 | 58.8 | 119.0 | 70.4 | 1.45 | 0.23 | 0.00 | 50.265 | ******* |
| 5 | 0.200 | 5.5 | 58.6 | 119.2 | 70.4 | 1.60 | 0.08 | 0.00 | 100.531 | ******* |
| 6 | 0.200 | 5.5 | 58.6 | 119.4 | 70.4 | 1.65 | 0.04 | 0.00 | 150.796 | ******* |
| 7 | 0.200 | 5.5 | 58.6 | 119.6 | 70.4 | 1.70 | 0.00 | 0.00 | ******* | ******* |

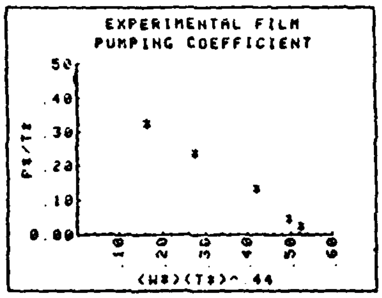
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0.0000 | 0.4216 | 0.9221 | 0.4573 | 0.0000 | 1.8746 | 0.0000 | 90.79 | 36.32 | 36.32 | 0.031 |
| 2 | 0.1712 | 0.3020 | 0.9205 | 0.3281 | 0.1651 | 1.8743 | 0.3208 | 90.91 | 42.09 | 36.37 | 0.031 |
| 3 | 0.2921 | 0.2187 | 0.9179 | 0.2383 | 0.2813 | 1.8571 | 0.5424 | 90.27 | 45.78 | 36.11 | 0.031 |
| 4 | 0.4369 | 0.1220 | 0.9160 | 0.1332 | 0.4204 | 1.8827 | 0.8226 | 91.66 | 51.34 | 36.67 | 0.031 |
| 5 | 0.5176 | 0.0428 | 0.9157 | 0.0467 | 0.4980 | 1.8746 | 0.9703 | 91.26 | 53.01 | 36.51 | 0.031 |
| 6 | 0.5490 | 0.0214 | 0.9154 | 0.0234 | 0.5281 | 1.8746 | 1.0292 | 91.29 | 54.67 | 36.52 | 0.031 |
| 7 | ****** | 0.0000 | 0.9151 | 0.0000 | ****** | 1.8746 | 0.0000 | 91.31 | ****** | 36.53 | 0.031 |

Table 2. Straight Stack L/D=1.25: Off Design Performance 50% Design

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | VE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | ******* | 0 0000 | 0 9221 | 0.0000 | ******** | 1.875 | ******* | ****** |
| 2 | ******* | 0 0000 | 0 9205 | 0 0000 | ******** | 2.195 | ******* | ****** |
| 3 | ******* | 0.0000 | 0 9179 | 0.0000 | ******** | 2 400 | ******* | ****** |
| 4 | ******* | 0 0000 | 0.9160 | 0.0000 | ******** | 2.705 | ******* | ****** |
| 5 | ******* | 0 0000 | 0.9157 | 0 0000 | ******** | 2 845 | ******* | ****** |
| 6 | ******* | 0 0000 | 0 9154 | 0.0000 | ******** | 2.904 | ******* | ****** |
| 7 | ******* | 0.0000 | 0 9151 | 0.0000 | ******** | ****** | ******* | ****** |



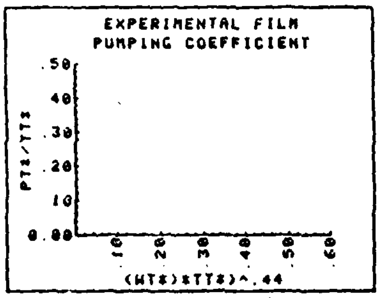
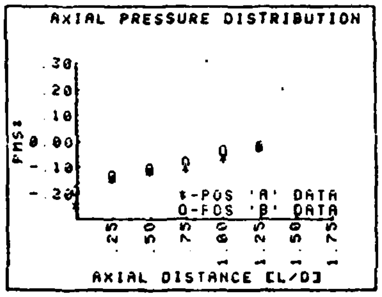




Table 2.  PCD (cont)

MIXING STACK DATA FOR RUN 7

| TOP (POSITION 'A') DATA | | | | DIAGONAL (POSITION 'B') DATA | | | |
|---|---|---|---|---|---|---|---|
| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* | X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
| 0.00 | -0.460 | 82 | -0.246 | 0.00 | -0.360 | 82 | -0.192 |
| 0.25 | -0.270 | 36 | -0.144 | 0.25 | -0.250 | 36 | -0.134 |
| 0.50 | -0.220 | 12 | -0.118 | 0.50 | -0.190 | 12 | -0.102 |
| 0.75 | -0.190 | 10 | -0.102 | 0.75 | -0.150 | 10 | -0.080 |
| 1.00 | -0.120 | 6 | -0.064 | 1.00 | -0.070 | 6 | -0.037 |
| 1.25 | -0.050 | 0 | -0.027 | 1.25 | -0.030 | 0 | -0.016 |



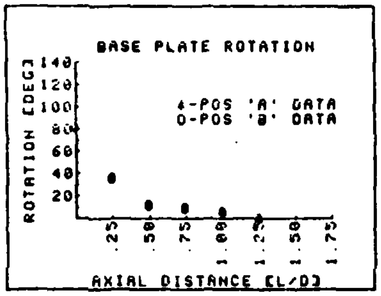
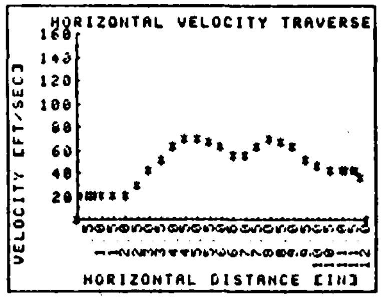




Table 2. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 09 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN]: | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O]: | 0.00 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| V[FT/SEC]: | 0.00 | 21.11 | 21.11 | 21.11 | 21.11 | 21.11 | 21.11 |
| POSIT[IN]: | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O]: | 0.10 | 0.20 | 0.40 | 0.60 | 0.90 | 1.10 | 1.10 |
| V[FT/SEC]: | 21.11 | 29.85 | 42.22 | 51.71 | 63.33 | 70.01 | 70.01 |
| POSIT[IN]: | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O]: | 1.00 | 0.90 | 0.70 | 0.70 | 0.90 | 1.10 | 1.00 |
| V[FT/SEC]: | 66.75 | 63.33 | 55.85 | 55.85 | 63.33 | 70.01 | 66.75 |
| POSIT[IN]: | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O]: | 0.90 | 0.60 | 0.50 | 0.40 | 0.40 | 0.40 | 0.40 |
| V[FT/SEC]: | 63.33 | 51.71 | 47.20 | 42.22 | 42.22 | 42.22 | 42.22 |
| POSIT[IN]: | 11.60 | 11.80 | 12.00 | | | | |
| P[IN H2O]: | 0.40 | 0.30 | 0.00 | | | | |
| V[FT/SEC]: | 42.22 | 36.56 | 0.00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 09 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN]: | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O]: | 0.00 | 0.20 | 0.45 | 0.60 | 0.80 | 0.50 | 1.10 |
| V[FT/SEC] | 0.00 | 29.85 | 44.78 | 51.71 | 59.70 | 63.33 | 70.01 |
| POSIT[IN]: | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O]: | 1.20 | 1.20 | 1.10 | 1.00 | 1.00 | 1.10 | 1.10 |
| V[FT/SEC]: | 73.12 | 73.12 | 70.01 | 66.75 | 66.75 | 70.01 | 70.01 |
| POSIT[IN]: | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O]: | 1.10 | 0.90 | 0.80 | 0.90 | 1.00 | 1.00 | 1.00 |
| V[FT/SEC]: | 70.01 | 63.33 | 59.70 | 63.33 | 66.75 | 66.75 | 66.75 |
| POSIT[IN]: | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O]: | 0.90 | 1.00 | 1.00 | 1.20 | 1.40 | 1.40 | 1.30 |
| V[FT/SEC]: | 63.33 | 66.75 | 66.75 | 73.12 | 78.98 | 78.98 | 76.11 |
| POSIT[IN]: | 11.60 | 11.80 | 12.00 | | | | |
| P[IN H2O]: | 1.10 | 0.90 | 0.00 | | | | |
| V[FT/SEC]: | 70.01 | 63.33 | 0.00 | | | | |

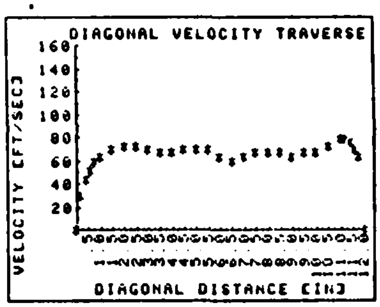



Table 2. VTD

DATA TAKEN ON: 1 OCT 81
DATA TAKEN BY: DRUCKER

NOZZLE AM/AP AREA RATIO: 2.50

COMMENTS
REDUCED FLOW: 3/4 DESIGN FLOW

MIXING STACK INFORMATION
- LENGTH 14.63 [IN]
- DIAMETER 11.70 [IN]
- L/D RATIO: 1.25
- S/D RATIO: 6.50

PRIMARY NOZZLE INFORMATION:
- TILT ANGLE 15.0 [DEG]
- ROTATION ANGLE: 20 [DEG]
- AREA PER NOZZLE: 10.752 [IN2]
- NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION:
- ORIFICE DIAMETER: 6.902 [IN]
- ORIFICE BETA: 0.497
- UPTAKE AREA: 107.510 [IN2]
- ATM. PRESSURE: 30.00 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0.400 | 12.4 | 60.4 | 114.8 | 70.4 | 1.90 | 1.76 | 0.00 | 0.000 | ******* |
| 2 | 0.400 | 12.4 | 60.2 | 115.0 | 70.4 | 2.40 | 1.25 | 0.00 | 12.566 | ******* |
| 3 | 0.400 | 12.4 | 60.4 | 115.2 | 70.6 | 2.70 | 0.90 | 0.00 | 25.133 | ******* |
| 4 | 0.405 | 12.5 | 60.6 | 115.6 | 70.4 | 3.15 | 0.51 | 0.00 | 50.265 | ******* |
| 5 | 0.400 | 12.5 | 60.0 | 115.6 | 70.6 | 3.45 | 0.19 | 0.00 | 100.531 | ******* |
| 6 | 0.405 | 12.5 | 60.2 | 115.8 | 70.6 | 3.55 | 0.10 | 0.00 | 150.796 | ******* |
| 7 | 0.400 | 12.5 | 59.8 | 115.8 | 70.8 | 3.65 | 0.01 | 0.00 | ******* | ******* |

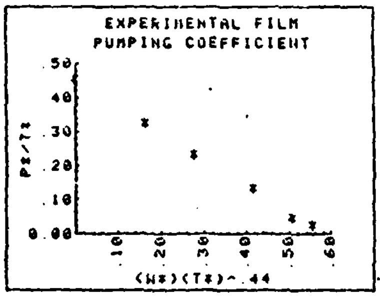
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0.0000 | 0.4222 | 0.9227 | 0.4576 | 0.0000 | 2.6078 | 0.0000 | 136.35 | 54.55 | 54.55 | 0.046 |
| 2 | 0.1706 | 0.3003 | 0.9224 | 0.3256 | 0.1647 | 2.8083 | 0.4792 | 136.26 | 63.06 | 54.51 | 0.046 |
| 3 | 0.2696 | 0.2166 | 0.9224 | 0.2348 | 0.2795 | 2.8078 | 0.8131 | 136.16 | 68.99 | 54.47 | 0.046 |
| 4 | 0.4344 | 0.1218 | 0.9214 | 0.1322 | 0.4190 | 2.8185 | 1.2244 | 136.65 | 76.51 | 54.66 | 0.046 |
| 5 | 0.5299 | 0.0454 | 0.9210 | 0.0493 | 0.5112 | 2.8202 | 1.4944 | 136.62 | 81.33 | 54.65 | 0.046 |
| 6 | 0.5767 | 0.0239 | 0.9215 | 0.0259 | 0.5564 | 2.8196 | 1.6262 | 136.61 | 83.68 | 54.65 | 0.046 |
| 7 | ****** | 0.0024 | 0.9210 | 0.0026 | ****** | 2.8207 | 2.6765 | 136.63 | ****** | 54.66 | 0.046 |

Table 3. Straight Stack L/D=1.25: Off Design Performance 75% Design

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | WM | WT | VE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | ****** | 0.0000 | 0.9227 | 0.0000 | ******* | 2.608 | ******* | ****** |
| 2 | ****** | 0.0000 | 0.9224 | 0.0000 | ******* | 3.288 | ******* | ****** |
| 3 | ****** | 0.0000 | 0.9224 | 0.0000 | ******* | 3.621 | ******* | ****** |
| 4 | ****** | 0.0000 | 0.9214 | 0.0000 | ******* | 4.043 | ******* | ****** |
| 5 | ****** | 0.0000 | 0.9218 | 0.0000 | ******* | 4.315 | ******* | ****** |
| 6 | ****** | 0.0000 | 0.9215 | 0.0000 | ******* | 4.446 | ******* | ****** |
| 7 | ****** | 0.0000 | 0.9218 | 0.0000 | ******* | ****** | ******* | ****** |



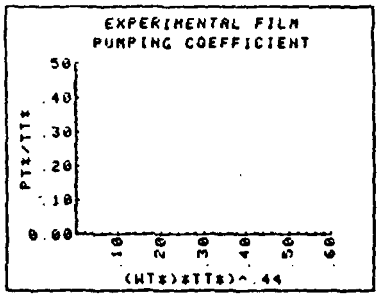




Table 3. PCD (cont)

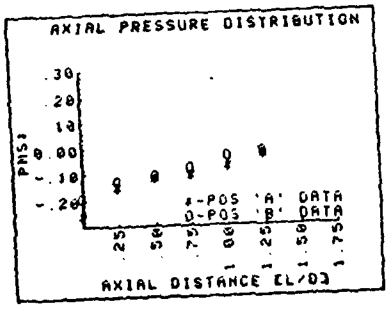
MIXING STACK DATA FOR RUN 7

TOP (POSITION 'A') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PHS* |
|---|---|---|---|
| 0.00 | -1.050 | 66 | -0.261 |
| 0.25 | -0.630 | 15 | -0.151 |
| 0.50 | -0.460 | 10 | -0.115 |
| 0.75 | -0.430 | 9 | -0.103 |
| 1.00 | -0.290 | 7 | -0.069 |
| 1.25 | -0.100 | 2 | -0.024 |

DIAGONAL (POSITION 'B') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PHS* |
|---|---|---|---|
| 0.00 | -0.800 | 86 | -0.191 |
| 0.25 | -0.540 | 15 | -0.129 |
| 0.50 | -0.430 | 10 | -0.103 |
| 0.75 | -0.310 | 9 | -0.074 |
| 1.00 | -0.130 | 7 | -0.031 |
| 1.25 | -0.060 | 2 | -0.014 |



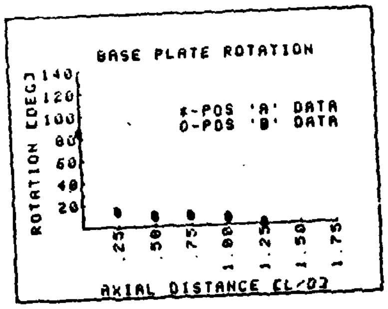
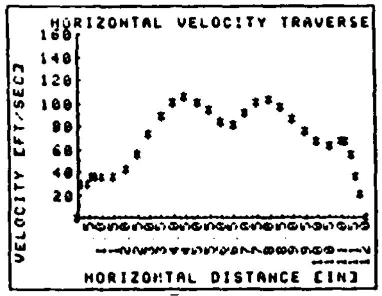




Table 3. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 09 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN]: | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O]: | 0.00 | 0.20 | 0.20 | 0.30 | 0.30 | 0.30 | 0.30 |
| V[FT/SEC]: | 0.00 | 29.88 | 29.88 | 36.59 | 36.59 | 36.59 | 36.59 |
| POSIT[IN]: | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O]: | 0.40 | 0.70 | 1.20 | 1.80 | 2.30 | 2.50 | 2.30 |
| V[FT/SEC]: | 42.25 | 55.90 | 73.19 | 89.63 | 101.32 | 105.64 | 101.32 |
| POSIT[IN]: | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O]: | 2.00 | 1.60 | 1.50 | 1.90 | 2.30 | 2.40 | 2.10 |
| V[FT/SEC]: | 94.48 | 84.51 | 81.82 | 92.09 | 101.32 | 103.50 | 96.82 |
| POSIT[IN]: | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O]: | 1.70 | 1.30 | 1.00 | 0.90 | 1.00 | 1.00 | 0.70 |
| V[FT/SEC]: | 87.11 | 76.17 | 66.81 | 63.38 | 66.81 | 66.81 | 55.90 |
| POSIT[IN]: | 11.60 | 11.80 | 12.00 | | | | |
| P[IN H2O]: | 0.30 | 0.10 | 0.00 | | | | |
| V[FT/SEC]: | 36.59 | 21.13 | 0.00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 09 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN]: | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O]: | 0.00 | 0.50 | 1.20 | 1.50 | 1.80 | 2.00 | 2.40 |
| V[FT/SEC]: | 0.00 | 47.24 | 73.19 | 81.92 | 89.63 | 94.48 | 103.50 |
| POSIT[IN]: | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O]: | 2.80 | 2.40 | 2.10 | 2.00 | 2.30 | 2.50 | 2.40 |
| V[FT/SEC]: | 111.79 | 103.50 | 96.82 | 94.48 | 101.32 | 105.64 | 103.50 |
| POSIT[IN]: | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O]: | 2.10 | 1.90 | 1.80 | 2.00 | 2.20 | 2.20 | 2.10 |
| V[FT/SEC]: | 96.82 | 92.09 | 89.63 | 94.48 | 99.09 | 99.09 | 96.82 |
| POSIT[IN]: | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O]: | 2.10 | 2.20 | 2.60 | 3.10 | 3.20 | 3.10 | 3.00 |
| V[FT/SEC]: | 96.82 | 99.09 | 107.73 | 117.63 | 119.51 | 117.63 | 115.72 |
| POSIT[IN]: | 11.60 | 11.80 | 12.00 | | | | |
| P[IN H2O]: | 2.70 | 2.30 | 0.10 | | | | |
| V[FT/SEC]: | 109.78 | 101.32 | 21.13 | | | | |

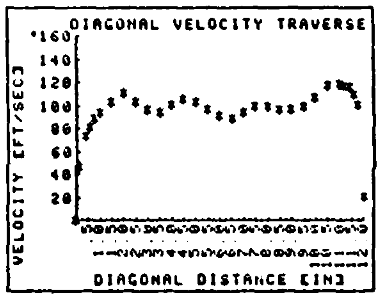



Table 3. VTD

DATA TAKEN ON: 03 OCT 81
DATA TAKEN BY: DRUCKER

NOZZLE AM/AP AREA RATIO: 2.50

COMMENTS:
FLOW RATE 1 2X DESIGN FLOW

MIXING STACK INFORMATION
LENGTH 14 63 [IN]
DIAMETER 11 70 [IN]
L/D RATIO: 1.25
S/D RATIO: 0 50

PRIMARY NOZZLE INFORMATION:
TILT ANGLE 15.0 [DEG]
ROTATION ANGLE: 20 [DEG]
AREA PER NOZZLE: 10 752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION:
ORIFICE DIAMETER: 6 902 [IN]
ORIFICE BETA: 0 497
UPTAKE AREA: 107.510 [IN2]
ATM PRESSURE: 29.98 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 965 | 31.7 | 54 2 | 105.8 | 65.4 | [illegible] | 4 39 | 0.00 | 0 000 | ******* |
| 2 | 0.970 | 31.8 | 54 6 | 106 2 | 65.8 | [illegible] | 3 08 | 0.00 | 12 566 | ******* |
| 3 | 0 965 | 31.7 | 54.6 | 106.4 | 65.[illegible] | [illegible] | 2.19 | 0.00 | 25.133 | ******* |
| 4 | 0.965 | 31 8 | 54.4 | 106.4 | 66.[illegible] | 7.80 | 1.20 | 0.00 | 50.265 | ******* |
| 5 | 0 960 | 31.6 | 54.2 | 106.4 | 66.4 | 8.45 | 0.45 | 0.00 | 100.531 | ******* |
| 6 | 0.965 | 31 7 | 54.0 | 106.6 | 66.4 | 8 70 | 0.25 | 0.00 | 150.796 | ******* |
| 7 | 0 965 | 31.7 | 54.0 | 106 4 | 66.6 | [illegible].80 | 0.02 | 0.00 | ******* | ******* |

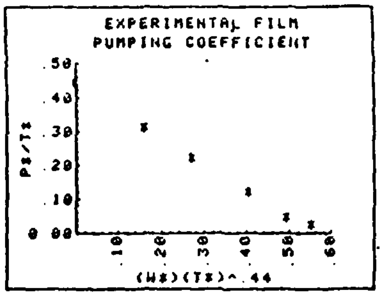
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0.0000 | 0.4113 | 0.9286 | 0.4430 | 0.0000 | 4.5117 | 0.0000 | 217.22 | 86.89 | 86.90 | 0.075 |
| 2 | 0 1672 | 0.2896 | 0 9286 | 0.3119 | 0.1618 | 4.5170 | 0.7552 | 216.93 | 100.15 | 86.78 | 0 074 |
| 3 | 0.2624 | 0.2073 | 0 9263 | 0.2233 | 0.2733 | 4.5099 | 1.2737 | 216.19 | 109.03 | 86 48 | 0.074 |
| 4 | 0.4173 | 0.1130 | 0.9286 | 0.1225 | 0.4039 | 4.5179 | 1.8953 | 216.04 | 119.81 | 86.43 | 0.074 |
| 5 | 0 5124 | 0.0431 | 0.9293 | 0.0464 | 0.4961 | 4.5046 | 2.3082 | 215.01 | 126.92 | 86.01 | 0.074 |
| 6 | 0.5723 | 0.0239 | 0.9290 | 0.0257 | 0.5541 | 4.5091 | 2.5806 | 215.19 | 131 62 | 86.00 | 0.074 |
| 7 | ****** | 0.0019 | 0.9297 | 0.0021 | ****** | 4.3126 | 3.7990 | 215.16 | ****** | 86.07 | 0.074 |

Table 4. Straight Stack L/D=1.25: Off Design Performance 120% Design

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | ****** | 0 0000 | 0.9286 | 0.0000 | ******* | 4 512 | ******* | ****** |
| 2 | ****** | 0 0000 | 0.9286 | 0.0000 | ******* | 5 272 | ******* | ****** |
| 3 | ****** | 0.0000 | 0 9283 | 0.0000 | ******* | 5.784 | ******* | ****** |
| 4 | ****** | 0.0000 | 0.9286 | 0.0000 | ******* | 6.403 | ******* | ****** |
| 5 | ****** | 0.0000 | 0 9293 | 0.0000 | ******* | 6 813 | ******* | ****** |
| 6 | ****** | 0 0000 | 0 9290 | 0.0000 | ******* | 7.090 | ******* | ****** |
| 7 | ****** | 0.0000 | 0 9297 | 0 0000 | ******* | ****** | ******* | ****** |



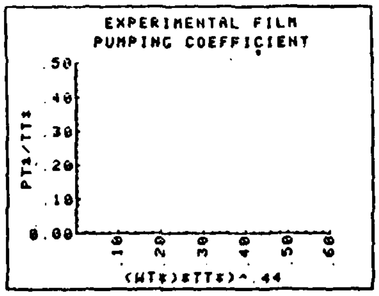
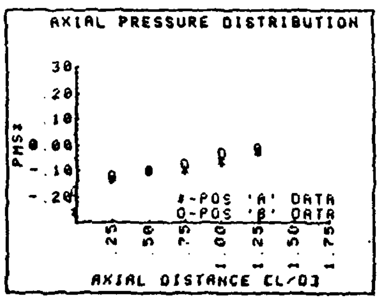




Table 4. PCD (cont)

MIXING STACK DATA FOR RUN 7

| TOP (POSITION 'A') DATA: | | | | DIAGONAL (POSITION 'B') DATA: | | | |
|---|---|---|---|---|---|---|---|
| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* | X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
| 0.00 | -2.700 | 89 | -0.258 | 0.00 | -1.840 | 89 | -0.176 |
| 0.25 | -1.380 | 20 | -0.132 | 0.25 | -1.240 | 20 | -0.119 |
| 0.50 | -1.060 | 15 | -0.101 | 0.50 | -1.020 | 15 | -0.098 |
| 0.75 | -1.050 | 8 | -0.101 | 0.75 | -0.790 | 8 | -0.076 |
| 1.00 | -0.670 | 6 | -0.064 | 1.00 | -0.320 | 6 | -0.031 |
| 1.25 | -0.270 | 0 | -0.026 | 1.25 | -0.160 | 0 | -0.015 |



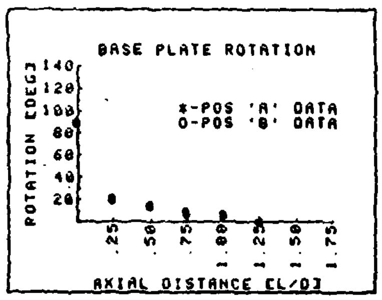
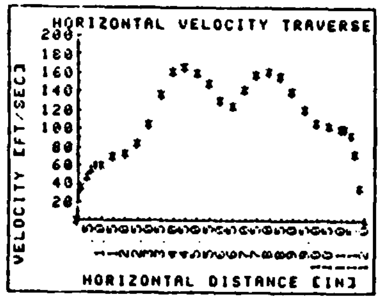




Table 4. MSD

| HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 07 DEGREES | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN]: | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O]: | 0.00 | 0.30 | 0.50 | 0.70 | 0.80 | 0.80 | 1.10 |
| V[FT/SEC]: | 0.00 | 36.46 | 47.07 | 55.69 | 59.54 | 59.54 | 69.82 |
| POSIT[IN]: | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O]: | 1.20 | 1.60 | 2.50 | 4.30 | 5.90 | 6.30 | 5.80 |
| V[FT/SEC]: | 72.92 | 84.20 | 105.25 | 138.04 | 161.69 | 167.08 | 160.31 |
| POSIT[IN]: | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O]: | 5.00 | 3.90 | 3.50 | 4.60 | 5.60 | 5.90 | 5.50 |
| V[FT/SEC]: | 148.85 | 131.46 | 124.53 | 142.77 | 157.53 | 161.69 | 156.11 |
| POSIT[IN]: | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O]: | 4.50 | 3.30 | 2.60 | 2.40 | 2.30 | 2.30 | 2.00 |
| V[FT/SEC]: | 141.21 | 120.92 | 107.34 | 103.12 | 100.95 | 100.95 | 94.14 |
| POSIT[IN]: | 11.60 | 11.60 | 12.00 | | | | |
| P[IN H2O]: | 1.20 | 0.30 | 0.00 | | | | |
| V[FT/SEC]: | 72.92 | 36.46 | 0.00 | | | | |




| DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 07 DEGREES | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN]: | 0.00 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.50 |
| P[IN H2O] | 0.00 | 0.90 | 3.60 | 4.30 | 4.80 | 5.80 | 7.50 |
| V[FT/SEC]: | 0.00 | 63.15 | 126.30 | 138.04 | 145.84 | 160.31 | 182.30 |
| POSIT[IN]: | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| P[IN H2O]: | 8.00 | 7.10 | 6.50 | 6.20 | 6.70 | 6.70 | 5.90 |
| V[FT/SEC]: | 188.28 | 177.37 | 169.71 | 165.75 | 172.30 | 172.30 | 161.69 |
| POSIT[IN] | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 |
| P[IN H2O]: | 4.70 | 3.60 | 3.70 | 4.90 | 5.40 | 5.10 | 4.50 |
| V[FT/SEC]: | 144.31 | 126.30 | 128.04 | 147.35 | 154.69 | 150.33 | 141.21 |
| POSIT[IN]: | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.20 | 11.40 |
| P[IN H2O]: | 4.00 | 4.50 | 5.80 | 7.40 | 8.20 | 7.90 | 7.30 |
| V[FT/SEC]: | 133.13 | 141.21 | 160.31 | 181.00 | 190.62 | 187.10 | 179.85 |
| POSIT[IN]: | 11.60 | 11.80 | 12.00 | | | | |
| P[IN H2O]: | 6.50 | 4.30 | 0.00 | | | | |
| V[FT/SEC]: | 169.71 | 130.04 | 0.00 | | | | |

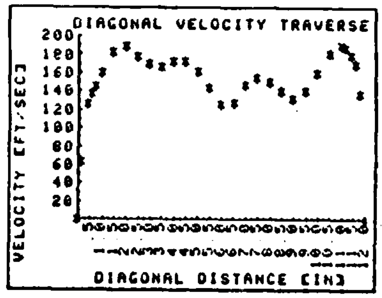



Table 4. VTD

DATA TAKEN ON 7 NOV 81
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO: 2.50

COMMENTS
CAL RUN SHROUDED STACK

MIXING STACK INFORMATION:
LENGTH: 17.55 [IN]
DIAMETER: 11.70 [IN]
L/D RATIO: 1.50
S/D RATIO: 0.50

PRIMARY NOZZLE INFORMATION:
TILT ANGLE: 15.0 [DEG]
ROTATION ANGLE: 20 [DEG]
AREA PER NOZZLE: 10.752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6.902 [IN]
ORIFICE BETA: 0.497
UPTAKE AREA: 107.510 [IN2]
ATM PRESSURE: 30.25 [INHG]

| N<br>RUN | POR<br>IN OF H2O | DPOR | TOR<br>DEGREES F | TUPT | TAMB | PUPT<br>IN OF H2O | PSEC | PTER | SECONDARY AREA<br>SQUARE INCHES | TERTIARY AREA<br>SQUARE INCHES |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.670 | 22.1 | 50.2 | 103.0 | 58.4 | 6.15 | 0.02 | 0.67 | 705.000 | 0.000 |
| 2 | 0.665 | 22.0 | 49.6 | 102.8 | 58.8 | 6.15 | 0.02 | 0.32 | 705.000 | 12.566 |
| 3 | 0.670 | 22.0 | 50.0 | 103.2 | 59.0 | 6.15 | 0.01 | 0.18 | 705.000 | 25.133 |
| 4 | 0.665 | 22.0 | 49.4 | 103.2 | 59.4 | 6.15 | 0.01 | 0.07 | 705.000 | 50.265 |
| 5 | 0.670 | 22.1 | 48.8 | 102.8 | 59.4 | 6.15 | 0.01 | 0.02 | 705.000 | 100.531 |
| 6 | 0.670 | 22.0 | 49.0 | 102.0 | 59.4 | 6.15 | 0.01 | 0.01 | ******* | ******* |

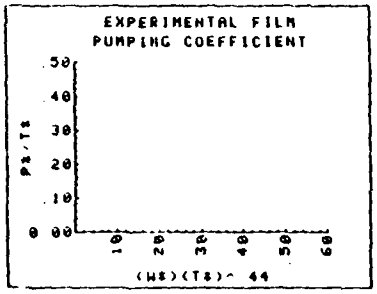
SECONDARY BOX

| N<br>RUN | W* | P* | T* | P*/T* | W*T^.44 | WP<br>LBM/SEC | WS<br>LBM/SEC | UP<br>FT/SEC | UM<br>FT/SEC | UUPT<br>FT/SEC | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** | 0.0027 | 0.9207 | 0.0029 | ****** | 3.8002 | 3.8461 | 170.50 | ****** | 71.41 | 0.061 |
| 2 | ****** | 0.0020 | 0.9218 | 0.0022 | ****** | 3.7939 | 3.3296 | 170.14 | ****** | 71.26 | 0.061 |
| 3 | ****** | 0.0014 | 0.9215 | 0.0015 | ****** | 3.7924 | 2.7100 | 170.19 | ****** | 71.28 | 0.061 |
| 4 | ****** | 0.0014 | 0.9222 | 0.0015 | ****** | 3.7946 | 2.7170 | 170.30 | ****** | 71.33 | 0.061 |
| 5 | ****** | 0.0014 | 0.9228 | 0.0015 | ****** | 3.8055 | 2.7170 | 170.60 | ****** | 71.48 | 0.061 |
| 6 | ****** | 0.0014 | 0.9228 | 0.0015 | ****** | 3.7961 | 2.7170 | 170.24 | ****** | 71.30 | 0.061 |

Table 5. Slots Closed

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | 0.0000 | 0.0909 | 0.9207 | 0.0987 | 0.0000 | ****** | 0.000 | ****** |
| 2 | 0.0649 | 0.0436 | 0.9218 | 0.0473 | 0.0626 | ****** | 0.246 | ****** |
| 3 | 0.0960 | 0.0239 | 0.9215 | 0.0259 | 0.0926 | ****** | 0.364 | ****** |
| 4 | 0.1169 | 0.0089 | 0.9222 | 0.0096 | 0.1128 | ****** | 0.444 | ****** |
| 5 | 0.1293 | 0.0027 | 0.9228 | 0.0029 | 0.1248 | ****** | 0.492 | ****** |
| 6 | ****** | 0.0014 | 0.9228 | 0.0015 | ******* | ****** | ******* | ****** |



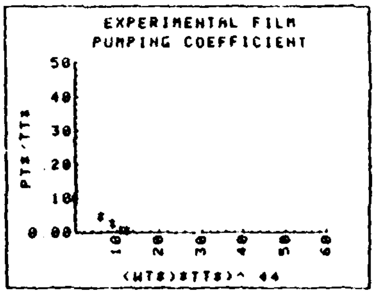




Table 5.  PCD (Tertiary)

DATA TAKEN ON: 7 NOV 81
DATA TAKEN BY: DRUCKER

NOZZLE AM/AP AREA RATIO: 2.50

COMMENTS:
SHROUDED STACK TER. FULL OPEN

MIXING STACK INFORMATION:

| | |
|---|---|
| LENGTH: | 17.55 [IN] |
| DIAMETER: | 11.70 [IN] |
| L/D RATIO: | 1.50 |
| S/D RATIO: | 0.50 |

PRIMARY NOZZLE INFORMATION:

| | |
|---|---|
| TILT ANGLE: | 15.0 [DEG] |
| ROTATION ANGLE: | 20 [DEG] |
| AREA PER NOZZLE: | 10.752 [IN2] |
| NUMBER OF NOZZLES: | 4 |

MISCELLANEOUS INFORMATION:

| | |
|---|---|
| ORIFICE DIAMETER: | 6.902 [IN] |
| ORIFICE BETA: | 0.497 |
| UPTAKE AREA: | 107.510 [IN2] |
| ATM. PRESSURE: | 30.25 [INHG] |

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0.670 | 22.1 | 48.0 | 102.2 | 59.6 | 2.90 | 3.40 | 0.01 | 0.000 | ******* |
| 2 | 0.670 | 22.1 | 48.4 | 102.4 | 59.8 | 3.80 | 2.42 | 0.01 | 12.566 | ******* |
| 3 | 0.670 | 22.1 | 48.4 | 102.4 | 59.0 | 4.50 | 1.76 | 0.01 | 25.133 | ******* |
| 4 | 0.665 | 22.0 | 48.4 | 102.4 | 60.0 | 5.20 | 0.99 | 0.01 | 50.265 | ******* |
| 5 | 0.670 | 22.2 | 48.6 | 102.6 | 60.2 | 5.85 | 0.37 | 0.01 | 100.531 | ******* |
| 6 | 0.670 | 22.2 | 48.4 | 102.6 | 60.2 | 6.00 | 0.21 | 0.01 | 150.796 | ******* |
| 7 | 0.670 | 22.1 | 48.6 | 102.6 | 60.4 | 6.20 | 0.01 | 0.01 | ******* | ******* |

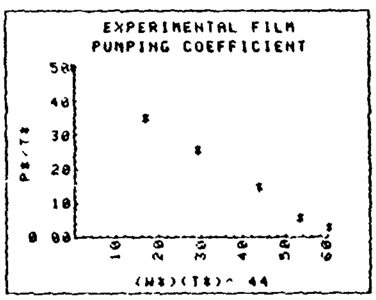
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0.0000 | 0.4646 | 0.9242 | 0.5028 | 0.0000 | 3.8085 | 0.0000 | 180.15 | 72.06 | 72.07 | 0.062 |
| 2 | 0.1777 | 0.3249 | 0.9242 | 0.3516 | 0.1716 | 3.8070 | 0.6763 | 179.68 | 83.61 | 71.80 | 0.062 |
| 3 | 0.3030 | 0.2371 | 0.9242 | 0.2565 | 0.2927 | 3.8070 | 1.1536 | 179.39 | 91.77 | 71.76 | 0.062 |
| 4 | 0.4555 | 0.1345 | 0.9246 | 0.1455 | 0.4400 | 3.7984 | 1.7300 | 178.64 | 101.48 | 71.46 | 0.061 |
| 5 | 0.5544 | 0.0500 | 0.9246 | 0.0541 | 0.5356 | 3.8140 | 2.1149 | 179.21 | 108.40 | 71.69 | 0.062 |
| 6 | 0.6264 | 0.0284 | 0.9246 | 0.0307 | 0.6051 | 3.8156 | 2.3899 | 179.10 | 113.16 | 71.68 | 0.062 |
| 7 | ****** | 0.0014 | 0.9249 | 0.0015 | ****** | 3.8062 | 2.7144 | 178.65 | ****** | 71.47 | 0.061 |

Table 5. PCD (Secondary)

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | ****** | 0 0013 | 0 9242 | 0 0014 | ******* | 3 800 | ******* | ****** |
| 2 | ****** | 0 0013 | 0 9242 | 0 0015 | ******* | 4 483 | ******* | ****** |
| 3 | ****** | 0 0013 | 0 9242 | 0 0015 | ******* | 4 961 | ******* | ****** |
| 4 | ****** | 0 0014 | 0 9246 | 0 0015 | ******* | 5 528 | ******* | ****** |
| 5 | ****** | 0 0014 | 0 9246 | 0 0015 | ******* | 5 930 | ******* | ****** |
| 6 | ****** | 0 0014 | 0 9246 | 0 0015 | ******* | 6 206 | ******* | ****** |
| 7 | ****** | 0 0014 | 0 9249 | 0 0015 | ******* | ****** | ******* | ****** |



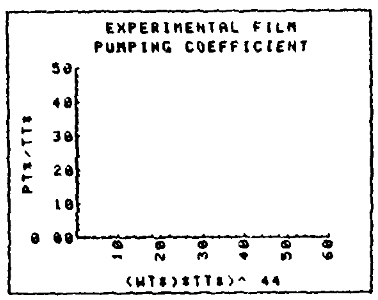
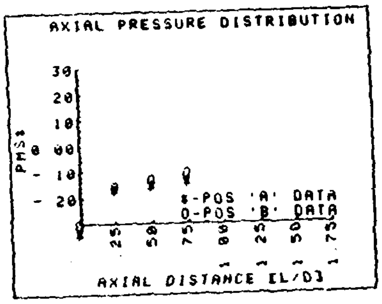




Table 5. PCD (Secondary)

MIXING STACK DATA FOR RUN 7

| TOP (POSITION 'A') DATA: X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* | DIAGONAL (POSITION 'B') DATA: X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|---|---|---|---|
| 0.00 | -2.500 | 5 | -0.340 | 0.00 | -2.240 | 5 | -0.305 |
| 0.25 | -1.250 | 6 | -0.170 | 0.25 | -1.140 | 6 | -0.155 |
| 0.50 | -1.130 | 5 | -0.154 | 0.50 | -0.960 | 5 | -0.131 |
| 0.75 | -1.000 | 20 | -0.136 | 0.75 | -0.760 | 20 | -0.103 |



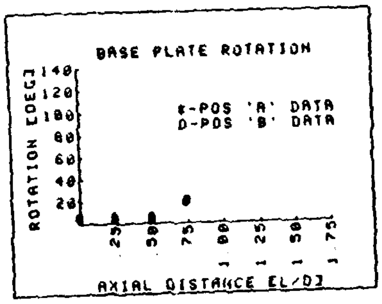
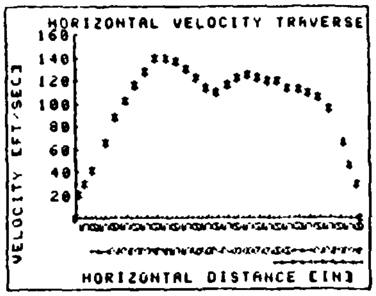




Table 5. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 29 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.50 | 0.80 | 1.50 | 2.00 | 2.50 |
| P[IN H2O] | 0.00 | 0.10 | 0.20 | 0.40 | 1.00 | 1.80 | 2.40 |
| V[FT/SEC] | 0.00 | 20.83 | 29.46 | 41.66 | 65.88 | 88.38 | 102.06 |
| POSIT[IN] | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 |
| P[IN H2O] | 3.10 | 3.80 | 4.50 | 4.50 | 4.30 | 3.90 | 3.50 |
| V[FT/SEC] | 115.99 | 128.42 | 139.75 | 139.75 | 136.61 | 130.10 | 123.25 |
| POSIT[IN] | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 |
| P[IN H2O] | 3.00 | 2.80 | 3.10 | 3.50 | 3.60 | 3.50 | 3.30 |
| V[FT/SEC] | 114.10 | 110.23 | 115.99 | 123.25 | 124.99 | 123.25 | 119.67 |
| POSIT[IN] | 10.00 | 10.50 | 11.00 | 11.50 | 12.00 | 12.50 | 13.20 |
| P[IN H2O] | 3.30 | 3.00 | 2.90 | 2.80 | 2.60 | 2.10 | 1.00 |
| V[FT/SEC] | 119.67 | 114.10 | 112.19 | 110.23 | 106.22 | 95.47 | 65.88 |
| POSIT[IN] | 13.50 | 13.80 | 14.00 | | | | |
| P[IN H2O] | 0.50 | 0.20 | 0.00 | | | | |
| V[FT/SEC] | 46.58 | 29.46 | 0.00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 29 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.50 | 0.80 | 1.50 | 2.00 | 2.50 |
| P[IN H2O] | 0.00 | 0.30 | 0.90 | 1.80 | 2.80 | 3.00 | 2.70 |
| V[FT/SEC] | 0.00 | 36.08 | 62.50 | 88.38 | 110.23 | 114.10 | 108.25 |
| POSIT[IN] | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 |
| P[IN H2O] | 2.50 | 3.00 | 3.90 | 4.20 | 4.10 | 3.40 | 2.70 |
| V[FT/SEC] | 104.16 | 114.10 | 130.10 | 135.01 | 133.39 | 121.47 | 108.25 |
| POSIT[IN] | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 |
| P[IN H2O] | 2.40 | 2.90 | 3.60 | 3.70 | 3.50 | 2.70 | 2.20 |
| V[FT/SEC] | 102.06 | 112.19 | 124.99 | 126.72 | 123.25 | 108.25 | 97.71 |
| POSIT[IN] | 10.00 | 10.50 | 11.00 | 11.50 | 12.00 | 12.50 | 13.20 |
| P[IN H2O] | 1.60 | 1.20 | 1.30 | 1.70 | 2.00 | 1.70 | 0.50 |
| V[FT/SEC] | 83.33 | 72.17 | 75.11 | 85.89 | 93.16 | 85.89 | 46.58 |
| POSIT[IN] | 13.50 | 13.80 | 14.00 | | | | |
| P[IN H2O] | 0.30 | 0.10 | 0.00 | | | | |
| V[FT/SEC] | 36.08 | 20.83 | 0.00 | | | | |

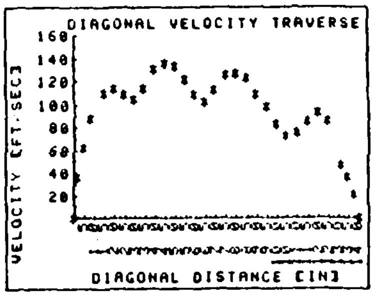



Table 5. VTD

DATA TAKEN ON: 10 NOV 81
DATA TAKEN BY: DRUCKER

NOZZLE AM/AP AREA RATIO: 2 50

COMMENTS
CHECK OF DATA OF 7 NOV 81

MIXING STACK INFORMATION:
- LENGTH: 17 55 [IN]
- DIAMETER: 11 70 [IN]
- L/D RATIO: 1 50
- S/D RATIO: 0 50

PRIMARY NOZZLE INFORMATION:
- TILT ANGLE: 15 0 [DEG]
- ROTATION ANGLE: 20 [DEG]
- AREA PER NOZZLE: 10 752 [IN2]
- NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION
- ORIFICE DIAMETER: 6 902 [IN]
- ORIFICE BETA: 0 497
- UPTAKE AREA: 107 510 [IN2]
- ATM PRESSURE: 30 28 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 680 | 22 0 | 56 0 | 109 0 | 64 6 | 2 85 | 3 42 | 0 01 | 0 000 | ******* |
| 2 | 0 675 | 21 9 | 56 0 | 109 0 | 64 6 | 3 80 | 2 39 | 0 01 | 12 566 | ******* |
| 3 | 0 660 | 22.1 | 55 8 | 109 0 | 64 8 | 4 50 | 1.75 | 0 01 | 25 133 | ******* |
| 4 | 0 675 | 22 0 | 55 8 | 109 0 | 64.8 | 5.20 | 1 00 | 0 01 | 50.265 | ******* |
| 5 | 0 680 | 22 2 | 55 8 | 109 0 | 65.2 | 5.85 | 0 37 | 0 01 | 100 531 | ******* |
| 6 | 0 680 | 22 2 | 55 6 | 109.0 | 65 2 | 6 00 | 0 21 | 0.01 | 150 796 | ******* |
| 7 | 0 680 | 22 1 | 55 8 | 109 0 | 65 4 | 6.15 | 0.01 | 0 01 | ******* | ******* |

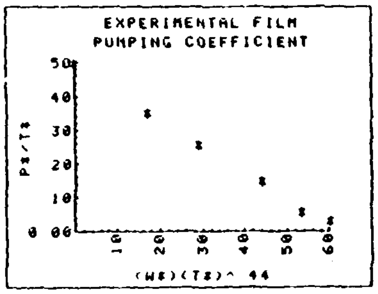
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^ 44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0 0000 | 0 4594 | 0 9219 | 0 4983 | 0 0000 | 3 7721 | 0 0000 | 180 38 | 72 16 | 72 16 | 0 062 |
| 2 | 0 1779 | 0 3241 | 0 9219 | 0 3516 | 0 1716 | 3 7635 | 0 6694 | 179 52 | 83 52 | 71 81 | 0 061 |
| 3 | 0 3029 | 0 2359 | 0 9223 | 0 2558 | 0 2923 | 3 7814 | 1 1454 | 180 09 | 92 08 | 72 04 | 0 062 |
| 4 | 0 4530 | 0 1359 | 0 9223 | 0.1474 | 0 4429 | 3 7728 | 1.7316 | 179 35 | 102 04 | 71 75 | 0 061 |
| 5 | 0 5556 | 0 0500 | 0 9230 | 0 0542 | 0 5364 | 3.7899 | 2 1058 | 179 89 | 108 83 | 71 96 | 0 062 |
| 6 | 0 6278 | 0 0284 | 0 9230 | 0 0308 | 0 6060 | 3 7907 | 2.3797 | 179 85 | 113 61 | 71 95 | 0 062 |
| 7 | ****** | 0 0014 | 0 9233 | 0 0015 | ****** | 3 7814 | 2 7028 | 179 33 | ****** | 71 74 | 0 061 |

Table 6. Verification of Table 5 (Partial Run)

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM LBM/SEC | WT LBM/SEC | VE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | ****** | 0 0013 | 0 9219 | 0 0015 | ******* | 3.772 | ******* | ****** |
| 2 | ****** | 0 0014 | 0 9219 | 0 0015 | ******* | 4 433 | ******* | ****** |
| 3 | ****** | 0 0013 | 0 9223 | 0 0015 | ******* | 4 927 | ******* | ****** |
| 4 | ****** | 0 0014 | 0 9223 | 0 0015 | ******* | 5 504 | ******* | ****** |
| 5 | ****** | 0 0014 | 0 9230 | 0 0015 | ******* | 5 896 | ******* | ****** |
| 6 | ****** | 0 0014 | 0 9230 | 0 0015 | ******* | 6 170 | ******* | ****** |
| 7 | ****** | 0 0014 | 0 9233 | 0 0015 | ******* | ****** | ******* | ****** |



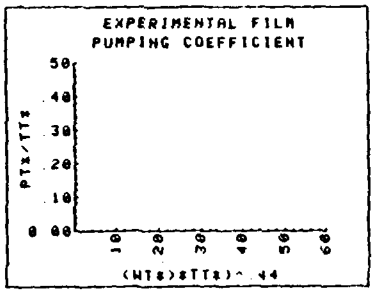




Table 6. PCD (cont)

DATA TAKEN ON 12 NOV 81
DATA TAKEN BY DRUCKER

NOZZLE AM AP AREA RATIO 2 50

COMMENTS
SHROUDED TWO RING SLOTTED STACK

MIXING STACK INFORMATION
LENGTH 17 55 [IN]
DIAMETER 11 70 [IN]
L/D RATIO 1 50
S/D RATIO 0 50

PRIMARY NOZZLE INFORMATION
TILT ANGLE 15 0 [DEG]
ROTATION ANGLE 20 [DEG]
AREA PER NOZZLE 10 752 [IN2]
NUMBER OF NOZZLES 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6 902 [IN]
ORIFICE BETA 0 497
UPTAKE AREA 107 510 [IN2]
ATM PRESSURE 30 03 [INHG]

| N RUN | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| | IN OF H20 | | DEGREES F | | | IN OF H20 | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 675 | 22 0 | 57 8 | 110 0 | 65 0 | 6 10 | 0 01 | 0 76 | 785 000 | 0 000 |
| 2 | 0 675 | 22 0 | 57 8 | 110 4 | 65 0 | 6 10 | 0 01 | 0 63 | 785 000 | 3 142 |
| 3 | 0 675 | 22 0 | 57 8 | 110 4 | 65 0 | 6 10 | 0 01 | 0 37 | 785 000 | 12 566 |
| 4 | 0 675 | 22 0 | 57 6 | 110 4 | 65 0 | 6 15 | 0 01 | 0 20 | 785 000 | 25 133 |
| 5 | 0 670 | 22 0 | 58 0 | 110 4 | 66 0 | 6 10 | 0 01 | 0 00 | 785 000 | 50 265 |
| 6 | 0 670 | 22 0 | 58 0 | 110 6 | 66 0 | 6 10 | 0 01 | 0 03 | 785 000 | 100 531 |
| 7 | 0 672 | 22 0 | 57 8 | 110 6 | 66 2 | 6 10 | 0 01 | 0 01 | ******* | ******* |

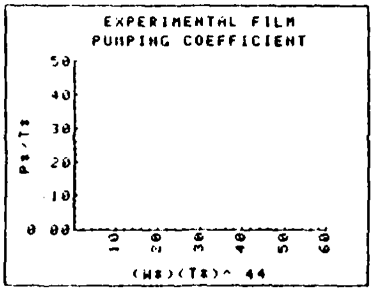
SECONDARY BOX

| N RUN | W* | P* | T* | P*/T* | W*T^ 44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LBM SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | ****** | 0 0014 | 0 9210 | 0 0015 | ****** | 3 7499 | 2 6926 | 179 63 | ****** | 71 86 | 0 061 |
| 2 | ****** | 0 0014 | 0 9218 | 0 0015 | ****** | 3 7499 | 2 6906 | 179 76 | ****** | 71 91 | 0 061 |
| 3 | ****** | 0 0014 | 0 9218 | 0 0015 | ****** | 3 7499 | 2 6906 | 179 76 | ****** | 71 91 | 0 061 |
| 4 | ****** | 0 0014 | 0 9218 | 0 0015 | ****** | 3 7507 | 2 6906 | 179 79 | ****** | 71 92 | 0 061 |
| 5 | ****** | 0 0014 | 0 9221 | 0 0015 | ****** | 3 7492 | 2 6901 | 179 72 | ****** | 71 90 | 0 061 |
| 6 | ****** | 0 0014 | 0 9218 | 0 0015 | ****** | 3 7492 | 2 6901 | 179 79 | ****** | 71 92 | 0 061 |
| 7 | ****** | 0 0014 | 0 9221 | 0 0015 | ****** | 3 7499 | 2 6895 | 179 82 | ****** | 71 94 | 0 061 |

Table 7. Slots Open

TERTIAPY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | 0 0000 | 0 1039 | 0 9210 | 0 1128 | 0 0000 | ****** | 0 000 | ****** |
| 2 | 0 0228 | 0 0861 | 0 9218 | 0 0934 | 0 0220 | ****** | 0 085 | ****** |
| 3 | 0 0699 | 0 0506 | 0 9218 | 0 0549 | 0 0674 | ****** | 0.262 | ****** |
| 4 | 0 1027 | 0 0273 | 0 9218 | 0 0296 | 0 0991 | ****** | 0.385 | ****** |
| 5 | 0 1299 | 0 0109 | 0 9221 | 0 0119 | 0 1254 | ****** | 0 487 | ****** |
| 6 | 0 1453 | 0 0034 | 0 9218 | 0 0037 | 0 1402 | ****** | 0 545 | ****** |
| 7 | ****** | 0 0014 | 0 9221 | 0 0015 | ******* | ****** | ******* | ****** |



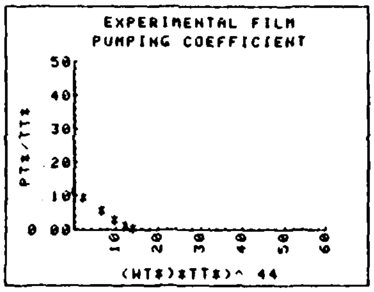




Table 7. PCD (Tertiary)

DATA TAKEN ON: 12 NOV 81
DATA TAKEN BY: DRUCKER

NOZZLE AM/AP AREA RATIO 2 50

COMMENTS:

MIXING STACK INFORMATION:
LENGTH 17 55 [IN]
DIAMETER 11 70 [IN]
L/D RATIO: 1 50
S/D RATIO 0 50

PRIMARY NOZZLE INFORMATION:
TILT ANGLE: 15 0 [DEG]
ROTATION ANGLE: 20 [DEG]
AREA PER NOZZLE: 10 752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6 902 [IN]
ORIFICE BETA: 0 497
UPTAKE AREA: 107 510 [IN2]
ATM PRESSURE: 30 03 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 675 | 22 1 | 57 0 | 110 6 | 66 8 | 2 90 | 3 37 | 0 02 | 0 000 | ******* |
| 2 | 0 675 | 22 1 | 57 4 | 110 8 | 66.8 | 3 90 | 2 35 | 0 01 | 12 566 | ******* |
| 3 | 0 670 | 22.0 | 57 2 | 110.8 | 67 0 | 4.50 | 1 68 | 0 01 | 25.133 | ******* |
| 4 | 0 670 | 22 0 | 57 8 | 110.6 | 67 4 | 5 20 | 0 99 | 0 01 | 50 265 | ******* |
| 5 | 0 670 | 22 0 | 57 8 | 110 8 | 67.6 | 5 80 | 0 38 | 0 01 | 100.531 | ******* |
| 6 | 0 670 | 22 0 | 57.6 | 111 0 | 67.6 | 6.00 | 0 22 | 0 01 | 150 796 | ******* |
| 7 | 0 670 | 22 0 | 57 4 | 111.0 | 67.8 | 6 10 | 0 01 | 0.01 | ******* | ******* |

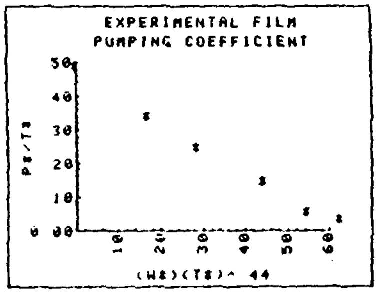
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^ 44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0 0000 | 0 4509 | 0 9232 | 0 4884 | 0 0000 | 3 7614 | 0 0000 | 181 87 | 72 75 | 72 75 | 0 062 |
| 2 | 0 1754 | 0 3160 | 0 9229 | 0 3425 | 0 1693 | 3 7599 | 0 6596 | 181 40 | 84 25 | 72 57 | 0 062 |
| 3 | 0 2972 | 0 2277 | 0 9232 | 0 2466 | 0 2870 | 3.7521 | 1 1153 | 180 73 | 92 05 | 72 30 | 0 062 |
| 4 | 0 4561 | 0 1348 | 0 9242 | 0 1458 | 0 4405 | 3 7529 | 1 7116 | 180 39 | 102 51 | 72 16 | 0 062 |
| 5 | 0 5655 | 0 0520 | 0 9243 | 0 0562 | 0 5462 | 3 7500 | 2.1204 | 180 05 | 109 63 | 72 03 | 0 062 |
| 6 | 0 6452 | 0 0301 | 0 9239 | 0 0325 | 0.6232 | 3 7507 | 2 4201 | 180 08 | 114 96 | 72 04 | 0 062 |
| 7 | ****** | 0 0014 | 0 9243 | 0 0015 | ****** | 3 7514 | 2 6855 | 180 02 | ****** | 72 01 | 0 062 |

Table 7. PCD (Secondary)

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | ****** | 0 0027 | 0 9232 | 0 0029 | ******* | 3 761 | ******* | ****** |
| 2 | ****** | 0 0013 | 0 9229 | 0 0015 | ******* | 4 420 | ******* | ****** |
| 3 | ****** | 0 0014 | 0 9232 | 0 0015 | ******* | 4 867 | ******* | ****** |
| 4 | ****** | 0 0014 | 0 9242 | 0 0015 | ******* | 5 464 | ******* | ****** |
| 5 | ****** | 0 0014 | 0 9243 | 0 0015 | ******* | 5 870 | ******* | ****** |
| 6 | ****** | 0 0014 | 0 9239 | 0 0015 | ******* | 6 171 | ******* | ****** |
| 7 | ****** | 0 0014 | 0 9243 | 0 0015 | ******* | ****** | ******* | ****** |



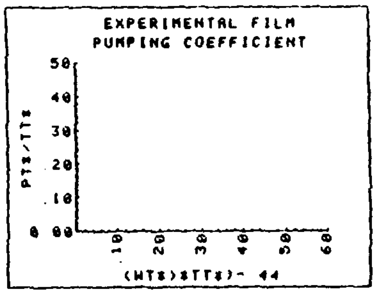




Table 7. PCD (Secondary)

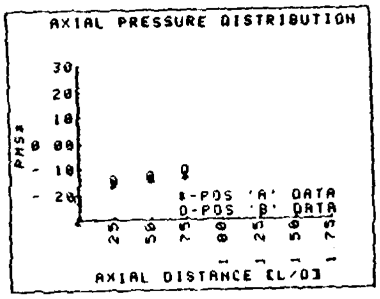
MIXING STACK DATA FOR RUN 7

TOP (POSITION 'A') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0.00 | -2.230 | 0 | -0.305 |
| 0.25 | -1.190 | 14 | -0.163 |
| 0.50 | -1.030 | 13 | -0.141 |
| 0.75 | -0.910 | 14 | -0.125 |

DIAGONAL (POSITION 'B') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0.00 | -1.600 | 0 | -0.219 |
| 0.25 | -1.070 | 14 | -0.146 |
| 0.50 | -0.920 | 13 | -0.126 |
| 0.75 | -0.780 | 14 | -0.107 |



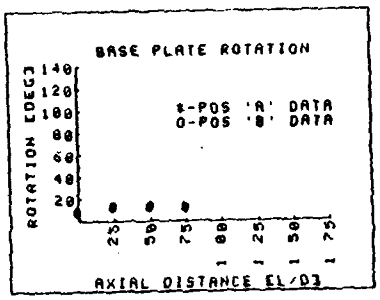
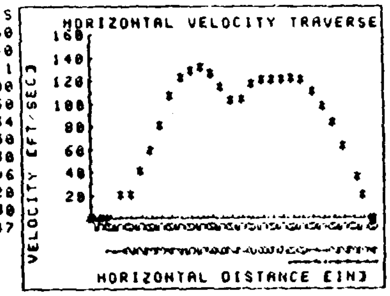




Table 7. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 13 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.50 | 0.80 | 1.50 | 2.00 | 2.50 |
| P[IN H2O] | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.10 | 0.40 |
| V[FT/SEC] | 0.00 | 0.00 | 0.00 | 0.00 | 21.06 | 21.06 | 42.11 |
| POSIT[IN] | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 |
| P[IN H2O] | 0.80 | 1.50 | 2.60 | 3.40 | 3.80 | 3.90 | 3.60 |
| V[FT/SEC] | 59.56 | 81.55 | 107.37 | 122.78 | 129.80 | 131.50 | 126.34 |
| POSIT[IN] | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 |
| P[IN H2O] | 3.00 | 2.40 | 2.50 | 3.10 | 3.30 | 3.30 | 3.30 |
| V[FT/SEC] | 115.33 | 103.16 | 105.28 | 117.24 | 120.96 | 120.96 | 120.96 |
| POSIT[IN] | 10.00 | 10.50 | 11.00 | 11.50 | 12.00 | 12.50 | 13.20 |
| P[IN H2O] | 3.40 | 3.30 | 2.80 | 2.20 | 1.60 | 0.90 | 0.30 |
| V[FT/SEC] | 122.78 | 120.96 | 111.42 | 98.76 | 84.23 | 63.17 | 36.47 |
| POSIT[IN] | 13.50 | 13.80 | 14.00 | | | | |
| P[IN H2O] | 0.10 | 0.00 | 0.00 | | | | |
| V[FT/SEC] | 21.06 | 0.00 | 0.00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 13 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.50 | 0.80 | 1.50 | 2.00 | 2.50 |
| P[IN H2O] | 0.00 | 0.40 | 1.20 | 2.20 | 3.90 | 4.60 | 4.10 |
| V[FT/SEC] | 0.00 | 42.11 | 72.94 | 98.76 | 131.50 | 142.81 | 134.83 |
| POSIT[IN] | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 |
| P[IN H2O] | 3.50 | 3.20 | 3.50 | 3.60 | 4.10 | 4.00 | 3.50 |
| V[FT/SEC] | 124.57 | 119.11 | 124.57 | 129.80 | 134.83 | 133.17 | 124.57 |
| POSIT[IN] | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 |
| P[IN H2O] | 2.80 | 2.30 | 2.50 | 3.00 | 3.60 | 3.60 | 3.40 |
| V[FT/SEC] | 111.42 | 100.98 | 105.28 | 115.33 | 126.34 | 126.34 | 122.78 |
| POSIT[IN] | 10.00 | 10.50 | 11.00 | 11.50 | 12.00 | 12.50 | 13.20 |
| P[IN H2O] | 2.90 | 2.70 | 2.80 | 3.50 | 4.20 | 3.90 | 1.60 |
| V[FT/SEC] | 113.39 | 109.41 | 111.42 | 124.57 | 136.46 | 131.50 | 84.23 |
| POSIT[IN] | 13.50 | 13.80 | 14.00 | | | | |
| P[IN H2O] | 0.70 | 0.20 | 0.00 | | | | |
| V[FT/SEC] | 55.71 | 29.78 | 0.00 | | | | |

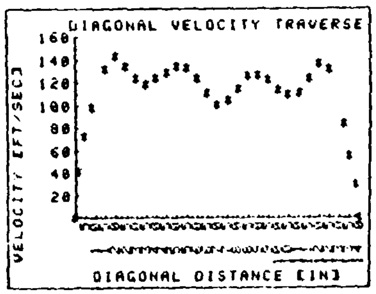



Table 7. VTD

DATA TAKEN ON 14 NOV 81
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO 2 50

COMMENTS
VERIFICATION OF 12 NOV RESULTS

| MIXING STACK INFORMATION | | PRIMARY NOZZLE INFORMATION | | MISCELLANEOUS INFORMATION | |
|---|---|---|---|---|---|
| LENGTH | 17 55 [IN] | TILT ANGLE | 15 0 [DEG] | ORIFICE DIAMETER | 6 902 [IN] |
| DIAMETER | 11 70 [IN] | ROTATION ANGLE | 20 [DEG] | ORIFICE BETA | 0 497 |
| L/D RATIO | 1 50 | AREA PER NOZZLE | 10 752 [IN2] | UPTAKE AREA | 107 510 [IN2] |
| S/D RATIO | 0 50 | NUMBER OF NOZZLES | 4 | ATM PRESSURE | 30 12 [INHG] |

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 665 | 22 0 | 59 4 | 112 0 | 66 6 | 6 10 | 0 02 | 0 73 | 785 000 | 0 000 |
| 2 | 0 665 | 22 0 | 59 2 | 112 0 | 66 8 | 6 10 | 0 01 | 0 61 | 785 000 | 3 142 |
| 3 | 0 665 | 22 0 | 59 2 | 112 2 | 67 0 | 6 10 | 0 01 | 0 35 | 785 000 | 12 566 |
| 4 | 0 665 | 22 0 | 59 2 | 112 0 | 67 0 | 6 10 | 0 01 | 0 20 | 785 000 | 25 133 |
| 5 | 0 665 | 22 0 | 59 2 | 112 2 | 67 0 | 6 10 | 0 01 | 0 08 | 785 000 | 50 265 |
| 6 | 0 665 | 22 0 | 59 2 | 112 2 | 67 2 | 6 10 | 0 01 | 0 02 | 785 000 | 100 531 |
| 7 | 0 665 | 22 0 | 59 2 | 112 2 | 67 2 | 6 10 | 0 01 | 0 01 | ******* | ******* |

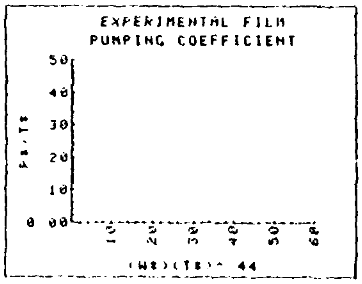
SECONDARY BOX

| N | W* | F* | T* | F* T* | W*T' 44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM SEC | LBM SEC | FT SEC | FT SEC | FT/SEC | |
| 1 | ****** | 0 0027 | 0 3206 | 0 0030 | ****** | 3 7498 | 3 8078 | 179 72 | ****** | 71 90 | 0 061 |
| 2 | ****** | 0 0014 | 0 3209 | 0 0015 | ****** | 3 7505 | 2 6920 | 179 75 | ****** | 71 91 | 0 061 |
| 3 | ****** | 0 0014 | 0 9210 | 0 0015 | ****** | 3 7505 | 2 6915 | 179 82 | ****** | 71 93 | 0 061 |
| 4 | ****** | 0 0014 | 0 9213 | 0 0015 | ****** | 3 7505 | 2 6915 | 179 75 | ****** | 71 91 | 0 061 |
| 5 | ****** | 0 0014 | 0 9210 | 0 0015 | ****** | 3 7505 | 2 6915 | 179 82 | ****** | 71 93 | 0 061 |
| 6 | ****** | 0 0014 | 0 9213 | 0 0015 | ****** | 3 7505 | 2 6910 | 179 82 | ****** | 71 93 | 0 061 |
| 7 | ****** | 0 0014 | 0 9213 | 0 0015 | ****** | 3 7505 | 2 6910 | 179 82 | ****** | 71 93 | 0 061 |

Table 8. Verification of Table 7 (Partial Run)

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | WM LBM/SEC | WT LBM/SEC | UE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 0000 | 0 0397 | 0 9206 | 0 1083 | 0 0000 | ****** | 0 000 | ****** |
| 2 | 0 0224 | 0 0833 | 0 9209 | 0 0904 | 0 0216 | ****** | 0 084 | ****** |
| 3 | 0 0680 | 0 0478 | 0 9210 | 0 0519 | 0 0655 | ****** | 0 255 | ****** |
| 4 | 0 1015 | 0 0266 | 0 9213 | 0 0289 | 0 0979 | ****** | 0 381 | ****** |
| 5 | 0 1258 | 0 0102 | 0 9210 | 0 0111 | 0 1214 | ****** | 0 472 | ****** |
| 6 | 0 1299 | 0 0027 | 0 9213 | 0 0030 | 0 1253 | ****** | 0 487 | ****** |
| 7 | ****** | 0 0014 | 0 9213 | 0 0015 | ******* | ****** | ******* | ****** |



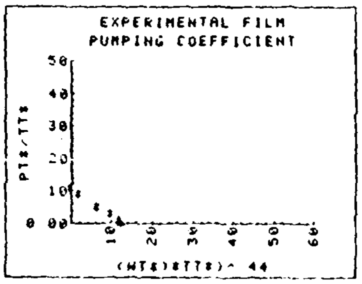




Table 8. PCD (Tertiary)

DATA TAKEN ON: 14 NOV 81
DATA TAKEN BY: DRUCKER

NOZZLE AN/AP AREA RATIO 2 50

COMMENTS:
VERIFICATION OF 12 NOV RESULTS

MIXING STACK INFORMATION
LENGTH 17 55 [IN]
DIAMETER: 11 70 [IN]
L/D RATIO 1 50
S/D RATIO 0 50

PRIMARY NOZZLE INFORMATION
TILT ANGLE: 15 0 [DEG]
ROTATION ANGLE: 20 [DEG]
AREA PER NOZZLE 10 752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6 902 [IN]
ORIFICE BETA 0 497
UPTAKE AREA 107 510 [IN2]
ATM PRESSURE: 30 12 [INHG]

| N<br>RUN | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA<br>SQUARE INCHES | TERTIARY AREA<br>SQUARE INCHES |
|---|---|---|---|---|---|---|---|---|---|---|
| | IN OF H2O | | DEGREES F | | | IN OF H2O | | | | |
| 1 | 0 665 | 22 0 | 59 0 | 112 2 | 67 4 | 2 90 | 3 34 | 0 01 | 0 000 | ******* |
| 2 | 0 662 | 21 9 | 59 0 | 112 2 | 67 6 | 3 80 | 2 30 | 0 01 | 12 566 | ******* |
| 3 | 0 665 | 22 1 | 58 6 | 112 2 | 67 8 | 4 50 | 1 69 | 0 01 | 25 133 | ******* |
| 4 | 0 665 | 22 0 | 59 0 | 112 2 | 67 8 | 5 20 | 0 96 | 0 01 | 50 265 | ******* |
| 5 | 0 662 | 21 9 | 59 0 | 112.2 | 68 0 | 5 75 | 0 34 | 0 01 | 100.531 | ******* |
| 6 | 0 665 | 22 0 | 58 6 | 112 2 | 68 0 | 5 95 | 0 20 | 0 01 | 150 796 | ******* |
| 7 | 0 665 | 22 1 | 58 4 | 112 0 | 68 2 | 6 10 | 0 01 | 0 01 | ******* | ******* |

SECONDARY BOX

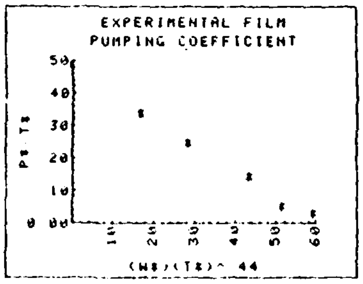
| N<br>RUN | W* | P* | T* | P*/T* | W*T^.44 |
|---|---|---|---|---|---|
| 1 | 0 0000 | 0 4487 | 0 9217 | 0 4869 | 0 0000 |
| 2 | 0 1745 | 0 3121 | 0 9220 | 0 3385 | 0 1684 |
| 3 | 0 2976 | 0 2279 | 0 9224 | 0 2470 | 0 2872 |
| 4 | 0 4498 | 0 1306 | 0 9224 | 0 1416 | 0 4341 |
| 5 | 0 5365 | 0 0466 | 0 9227 | 0 0505 | 0 5178 |
| 6 | 0 6156 | 0 0273 | 0 9227 | 0 0296 | 0 5942 |
| 7 | ****** | 0 0014 | 0 9234 | 0 0015 | ****** |

| N<br>RUN | WP<br>LBM/SEC | WS<br>LBM/SEC | UP<br>FT/SEC | UM<br>FT/SEC | UUPT<br>FT/SEC | UPT MACH |
|---|---|---|---|---|---|---|
| 1 | 3 7513 | 0 0000 | 181 32 | 72 53 | 72 54 | 0 062 |
| 2 | 3 7427 | 0 6530 | 180 45 | 83 73 | 72 19 | 0 062 |
| 3 | 3 7612 | 1 1194 | 181 07 | 92 23 | 72 44 | 0 062 |
| 4 | 3 7513 | 1 6873 | 180 27 | 101 96 | 72 11 | 0 062 |
| 5 | 3 7427 | 2 0080 | 179 59 | 107 37 | 71 84 | 0 061 |
| 6 | 3 7527 | 2 3100 | 180 00 | 112 88 | 72 01 | 0 061 |
| 7 | 3 7619 | 2 6805 | 180 30 | ****** | 72 13 | 0 062 |

Table 8. PCD (Secondary)

TERTIAPY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM·SEC | FT·SEC |
| 1 | ****** | 0 0013 | 0 9217 | 0 0015 | ******* | 3 751 | ******* | ****** |
| 2 | ****** | 0 0014 | 0 9220 | 0 0015 | ******* | 4 396 | ******* | ****** |
| 3 | ****** | 0 0013 | 0 9224 | 0 0015 | ******* | 4 861 | ******* | ****** |
| 4 | ****** | 0 0014 | 0 9224 | 0 0015 | ******* | 5 439 | ******* | ****** |
| 5 | ****** | 0 0014 | 0 9227 | 0 0015 | ******* | 5 751 | ******* | ****** |
| 6 | ****** | 0 0014 | 0 9227 | 0 0015 | ******* | 6 063 | ******* | ****** |
| 7 | ****** | 0 0014 | 0 9234 | 0 0015 | ******* | ****** | ******* | ****** |



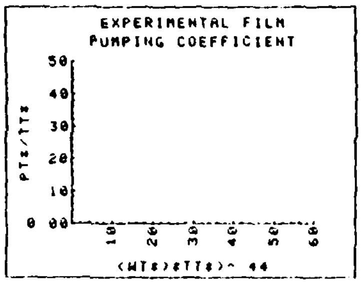




Table 8. PCD (Secondary)

DATA TAKEN ON 6 DEC 81
DATA TAKEN BY DRUCKER-EICK

NOZZLE AM AP AREA RATIO 2 50

COMMENTS
FLOW SEPERATION DATA

| MIXING STACK INFORMATION | | PRIMARY NOZZLE INFORMATION | | MISCELLANEOUS INFORMATION | |
|---|---|---|---|---|---|
| LENGTH | 17 55 [IN] | TILT ANGLE | 15 0 [DEG] | ORIFICE DIAMETER | 6 902 [IN] |
| DIAMETER | 11 70 [IN] | ROTATION ANGLE | 10 [DEG] | ORIFICE BETA | 0 497 |
| L/D RATIO | 1 50 | AREA PER NOZZLE | 10 752 [IN2] | UPTAKE AREA | 107 510 [IN2] |
| S/D RATIO | 0 50 | NUMBER OF NOZZLES | 4 | ATM PRESSURE | 30 19 [INHG] |

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 665 | 22 1 | 49 0 | 102 8 | 59 2 | 6 15 | 0 02 | 0 84 | 785 000 | 0 000 |
| 2 | 0 665 | 22 1 | 49 0 | 102 8 | 59 2 | 6 10 | 0 02 | 0 70 | 785 000 | 3 142 |
| 3 | 0 665 | 22 0 | 49 0 | 102 8 | 59 4 | 6 10 | 0 02 | 0 39 | 785 000 | 12 566 |
| 4 | 0 665 | 22 0 | 49 2 | 102 6 | 59 6 | 6 10 | 0 02 | 0 21 | 785 000 | 25 133 |
| 5 | 0 665 | 22 0 | 49 6 | 102 8 | 59 6 | 6 10 | 0 02 | 0 08 | 785 000 | 50 265 |
| 6 | 0 665 | 22 0 | 49 6 | 103 0 | 59 8 | 6 10 | 0 02 | 0 03 | 785 000 | 100 531 |
| 7 | 0 665 | 22 0 | 49 6 | 103 2 | 59 8 | 6 10 | 0 01 | 0 01 | ******* | ******* |

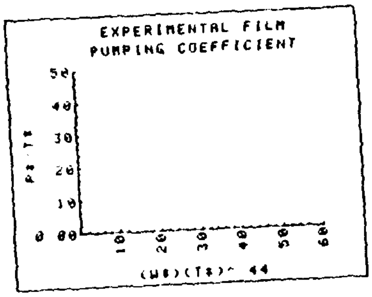
SECONDARY BOX

| N | W* | P* | T* | P* T* W*T^ 44 | | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | ****** | 0 0020 | 0 9225 | 0 0022 | ****** | 3 8010 | 3 3250 | 178 82 | ****** | 71 54 | 0 062 |
| 2 | ****** | 0 0020 | 0 9225 | 0 0022 | ****** | 3 8010 | 3 3250 | 178 82 | ****** | 71 54 | 0 062 |
| 3 | ****** | 0 0020 | 0 9229 | 0 0022 | ****** | 3 7924 | 3 3243 | 178 42 | ****** | 71 37 | 0 061 |
| 4 | ****** | [illegible] | [illegible] | [illegible] | ****** | [illegible] | 3 3237 | 178 32 | ****** | [illegible] | [illegible] |
| 5 | ****** | 0 0020 | 0 9232 | 0 0022 | ****** | 3 7901 | 3 3237 | 178 31 | ****** | 71 33 | 0 061 |
| 6 | ****** | 0 0020 | 0 9232 | 0 0022 | ****** | 3 7901 | 3 3230 | 178 30 | ****** | 71 36 | 0 061 |
| 7 | ****** | 0 0016 | 0 9229 | 0 0018 | ****** | 3 7901 | 2 9722 | 178 44 | ****** | 71 38 | 0 061 |

Table 9. 15/10 Nozzles: Slots Open

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | WM LBM/SEC | WT LBM/SEC | UE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.0000 | 0.1140 | 0.9225 | 0.1235 | 0.0000 | ****** | 0.000 | ****** |
| 2 | 0.0239 | 0.0950 | 0.9225 | 0.1029 | 0.0231 | ****** | 0.091 | ****** |
| 3 | 0.0711 | 0.0525 | 0.9228 | 0.0569 | 0.0666 | ****** | 0.270 | ****** |
| 4 | 0.1050 | 0.0287 | 0.9235 | 0.0310 | 0.1014 | ****** | 0.398 | ****** |
| 5 | 0.1256 | 0.0102 | 0.9232 | 0.0111 | 0.1212 | ****** | 0.476 | ****** |
| 6 | 0.1450 | 0.0034 | 0.9232 | 0.0037 | 0.1400 | ****** | 0.549 | ****** |
| 7 | ****** | 0.0014 | 0.9229 | 0.0015 | ******* | ****** | ******* | ****** |



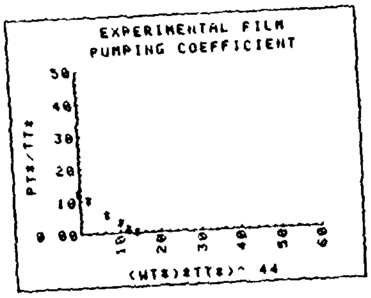




Table 9. PCD (Tertiary)

DATA TAKEN ON: 6 DEC 81
DATA TAKEN BY: DRUCKER/EICK
NOZZLE AM/AP AREA RATIO: 2 50

COMMENTS
FLOW SEPERATION DATA

MIXING STACK INFORMATION
LENGTH: 17 55 [IN]
DIAMETER: 11 70 [IN]
L/D RATIO: 1 50
S/D RATIO: 0 50

PRIMARY NOZZLE INFORMATION
TILT ANGLE: 15 0 [DEG]
ROTATION ANGLE: 10 [DEG]
AREA PER NOZZLE: 10 752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER: 6 982 [IN]
ORIFICE BETA: 0 497
UPTAKE AREA: 107 510 [IN2]
ATM PRESSURE: 30 19 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 670 | 22 0 | 48 6 | 102 6 | 59 8 | 3 10 | 3 29 | 0 01 | 0 000 | ******* |
| 2 | 0 665 | 21 9 | 48 6 | 102 6 | 59 8 | 3 90 | 2 37 | 0 01 | 12 566 | ******* |
| 3 | 0 665 | 22 1 | 48 4 | 102 6 | 60 0 | 4.55 | 1.76 | 0 01 | 25 133 | ******* |
| 4 | 0 665 | 22 0 | 49 0 | 102 6 | 60 0 | 5 20 | 0.98 | 0 01 | 50 265 | ******* |
| 5 | 0 662 | 22 0 | 48.4 | 102 6 | 60 2 | 5 75 | 0.39 | 0 02 | 100 531 | ******* |
| 6 | 0 662 | 22 0 | 49 0 | 102 8 | 60 4 | 5 95 | 0.22 | 0 02 | 150 796 | ******* |
| 7 | 0 665 | 22 1 | 48 8 | 103 2 | 60 4 | 6 20 | 0 02 | 0 02 | ******* | ******* |

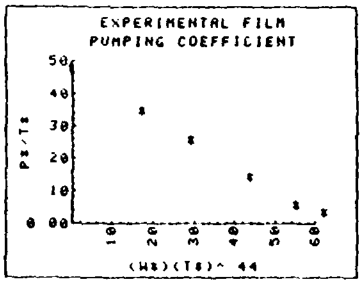
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM SEC | LBM SEC | FT SEC | FT SEC | FT/SEC | |
| 1 | 0 0000 | 0 4417 | 0 9239 | 0 4781 | 0 0000 | 3 7938 | 0 0000 | 179 86 | 71 95 | 71 95 | 0 062 |
| 2 | 0 1766 | 0 3211 | 0 9239 | 0 3476 | 0 1706 | 3 7852 | 0 6686 | 179 05 | 83 25 | 71 63 | 0 062 |
| 3 | 0 3030 | 0 2370 | 0 9242 | 0 2564 | 0 2926 | 3 8032 | 1 1522 | 179 63 | 91 89 | 71 86 | 0 062 |
| 4 | 0 4534 | 0 1332 | 0 9242 | 0 1442 | 0 4380 | 3 7924 | 1 7196 | 178 78 | 101 41 | 71 52 | 0 062 |
| 5 | 0 5716 | 0 0531 | 0 9246 | 0 0575 | 0 5523 | 3 7946 | 2 1691 | 178 63 | 109 10 | 71 46 | 0 061 |
| 6 | 0 6443 | 0 0300 | 0 9246 | 0 0325 | 0 6224 | 3 7924 | 2 4433 | 178 51 | 113 92 | 71 41 | 0 061 |
| 7 | ****** | 0 0020 | 0 9240 | 0 0022 | ****** | 3 8017 | 3 3211 | 178 99 | ****** | 71 60 | 0 062 |

Table 9. PCD (Secondary)

TERTIARY BOX

| N | WT* | FT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM SEC | FT/SEC |
| 1 | ****** | 0 0013 | 0 9239 | 0 0015 | ******* | 3 794 | ******* | ****** |
| 2 | ****** | 0 0014 | 0 9239 | 0 0015 | ******* | 4 454 | ******* | ****** |
| 3 | ****** | 0 0013 | 0 9242 | 0 0015 | ******* | 4 955 | ******* | ****** |
| 4 | ****** | 0 0014 | 0 9242 | 0 0015 | ******* | 5 512 | ******* | ****** |
| 5 | ****** | 0 0027 | 0 9246 | 0 0029 | ******* | 5 964 | ******* | ****** |
| 6 | ****** | 0 0020 | 0 9246 | 0 0022 | ******* | 6 236 | ******* | ****** |
| 7 | ****** | 0 0020 | 0 9240 | 0 0022 | ******* | ****** | ******* | ****** |



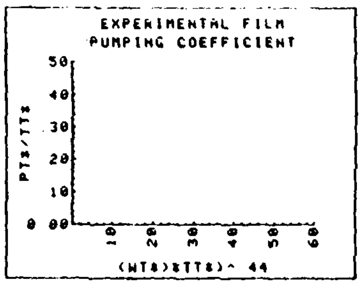




Table 9. PCD (Secondary)

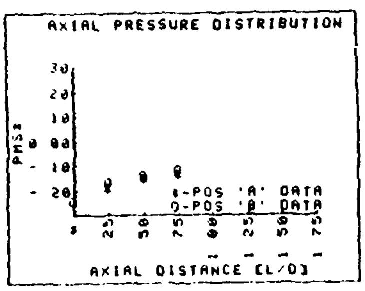
MIXING STACK DATA FOR RUN 7

TOP (POSITION 'A') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0.00 | -2.580 | 10 | -0.350 |
| 0.25 | -1.400 | 12 | -0.190 |
| 0.50 | -1.120 | 21 | -0.152 |
| 0.75 | -0.980 | 22 | -0.133 |

DIAGONAL (POSITION 'B') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0.00 | -1.770 | 10 | -0.240 |
| 0.25 | -1.230 | 22 | -0.167 |
| 0.50 | -1.030 | 21 | -0.140 |
| 0.75 | -0.860 | 22 | -0.117 |



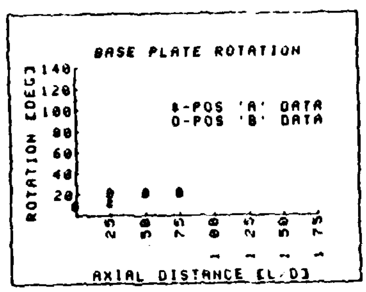
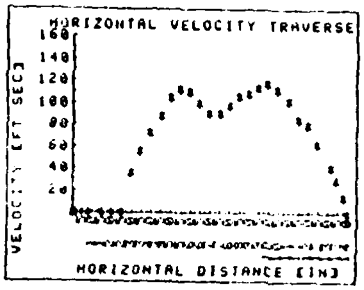




Table 9. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 12 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0 00 | 0 20 | 0 50 | 0 80 | 1 50 | 2 00 | 2 50 |
| P[IN H2O] | 0 00 | 0 00 | 0 00 | 0 00 | 0 00 | 0 00 | 0 00 |
| V[FT/SEC] | 0 00 | 0 00 | 0 00 | 0 00 | 0 00 | 0 00 | 0 00 |
| POSIT[IN] | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5 50 | 6 00 |
| P[IN H2O] | 0 30 | 0 70 | 1 20 | 1 00 | 2 50 | 2 90 | 2 75 |
| V[FT/SEC] | 36 12 | 55 17 | 72 24 | 88 47 | 104 26 | 112 30 | 109 35 |
| POSIT[IN] | 6 50 | 7 00 | 7 50 | 8 00 | 8 50 | 9 00 | 9 50 |
| P[IN H2O] | 2 30 | 1 90 | 1 90 | 2 20 | 2 60 | 2 70 | 3 00 |
| V[FT/SEC] | 100 01 | 90 90 | 90 90 | 97 81 | 106 33 | 108 36 | 114 22 |
| POSIT[IN] | 10 00 | 10 50 | 11 00 | 11 50 | 12 00 | 12 50 | 13 20 |
| P[IN H2O] | 3 20 | 2 90 | 2 40 | 1 70 | 1 50 | 0 90 | 0 40 |
| V[FT/SEC] | 117 96 | 112 30 | 102 16 | 85 58 | 80 76 | 62 56 | 41 71 |
| POSIT[IN] | 13 50 | 13 80 | 14 00 | | | | |
| P[IN H2O] | 0 20 | 0 05 | 0 00 | | | | |
| V[FT/SEC] | 29 49 | 14 75 | 0 00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 12 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0 00 | 0 20 | 0 50 | 0 80 | 1 50 | 2 00 | 2 50 |
| P[IN H2O] | 0 05 | 0 55 | 1 20 | 2 00 | 4 25 | 4 60 | 4 10 |
| V[FT/SEC] | 14 75 | 48 90 | 72 24 | 93 26 | 135 94 | 141 43 | 133 52 |
| POSIT[IN] | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5 50 | 6 00 |
| P[IN H2O] | 3 20 | 2 50 | 2 15 | 2 00 | 2 10 | 2 60 | 2 70 |
| V[FT/SEC] | 117 36 | 104 26 | 96 69 | 93 26 | 95 56 | 106 33 | 108 36 |
| POSIT[IN] | 6 50 | 7 00 | 7 50 | 8 00 | 8 50 | 9 00 | 9 50 |
| P[IN H2O] | 2 30 | 1 80 | 1 95 | 2 40 | 2 70 | 2 90 | 2 80 |
| V[FT/SEC] | 100 91 | 88 47 | 92 08 | 102 16 | 108 36 | 112 30 | 110 34 |
| POSIT[IN] | 10 00 | 10 50 | 11 00 | 11 50 | 12 00 | 12 50 | 13 20 |
| P[IN H2O] | 2 65 | 2 90 | 3 15 | 4 10 | 4 70 | 4 50 | 1 90 |
| V[FT/SEC] | 107 35 | 112 30 | 117 04 | 133 52 | 142 96 | 139 89 | 90 90 |
| POSIT[IN] | 13 50 | 13 80 | 14 00 | | | | |
| P[IN H2O] | 0 90 | 0 30 | 0 00 | | | | |
| V[FT/SEC] | 62 56 | 36 12 | 0 00 | | | | |

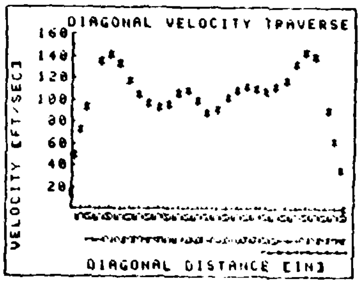



Table 9. VTD

DATA TAKEN ON 17 DEC 81
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO 2 50

COMMENTS
INITIAL DATA 7 3 DEG DIFFUSER

MIXING STACK INFORMATION
LENGTH 17 55 [IN]
DIAMETER 11 70 [IN]
L/D RATIO 1 50
S/D RATIO 0 50

PRIMARY NOZZLE INFORMATION
TILT ANGLE 15 0 [DEG]
ROTATION ANGLE 20 [DEG]
AREA PER NOZZLE 10 752 [IN2]
NUMBER OF NOZZLES 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6 902 [IN]
ORIFICE BETA 0 497
UPTAKE AREA 107 510 [IN2]
ATM PRESSURE 30 17 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | FLCR | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 655 | 22 0 | 44 2 | 95 0 | 47 2 | 6 10 | 0 01 | 0 53 | 785 000 | 0 000 |
| 2 | 0 650 | 22 0 | 44 6 | 96 0 | 48 2 | 6 10 | 0 01 | 0 39 | 785 000 | 3 142 |
| 3 | 0 650 | 22 0 | 44 8 | 97 2 | 48 4 | 6 10 | 0 01 | 0 13 | 785 000 | 12 566 |
| 4 | 0 655 | 22 0 | 45 0 | 97 6 | 49 0 | 6 10 | 0 01 | 0 05 | 785 000 | 25 133 |
| 5 | 0 655 | 22 0 | 44 6 | 97 8 | 49 0 | 6 10 | 0 01 | 0 02 | 785 000 | 50 265 |
| 6 | 0 655 | 22 0 | 44 4 | 97 8 | 49 6 | 6 10 | 0 01 | 0 01 | 785 000 | 100 531 |
| 7 | 0 655 | 22 0 | 44 6 | 98 0 | 49 6 | 6 10 | 0 01 | 0 00 | ******* | ******* |

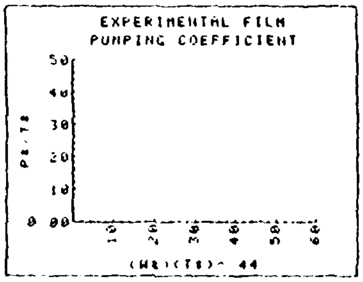
SECONDARY BOX

| N | WA | P* | T* | P*/T* | WRT/44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | ****** | 0 0014 | 0 9125 | 0 0015 | ****** | 3 8092 | 2 7459 | 177 10 | ****** | 70 84 | 0 061 |
| 2 | ****** | 0 0014 | 0 9127 | 0 0015 | ****** | 3 8077 | 2 7432 | 177 34 | ****** | 70 94 | 0 061 |
| 3 | ****** | 0 0014 | 0 9124 | 0 0015 | ****** | 3 8069 | 2 7426 | 177 44 | ****** | 70 98 | 0 061 |
| 4 | ****** | 0 0014 | 0 9120 | 0 0015 | ****** | 3 8061 | 2 7410 | 177 53 | ****** | 71 02 | 0 061 |
| 5 | ****** | 0 0013 | 0 9125 | 0 0015 | ****** | 3 8076 | 2 7410 | 177 66 | ****** | 71 07 | 0 061 |
| 6 | ****** | 0 0013 | 0 9135 | 0 0015 | ****** | 3 8084 | 2 7394 | 177 70 | ****** | 71 09 | 0 061 |
| 7 | ****** | 0 0013 | 0 9132 | 0 0015 | ****** | 3 8076 | 2 7394 | 177 73 | ****** | 71 10 | 0 061 |

Table 10. Slots Closed

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM | WT | VE |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | 0 0000 | 0 0717 | 0 9125 | 0 0785 | 0 0000 | ****** | 0 000 | ****** |
| 2 | 0 0180 | 0 0527 | 0 9127 | 0 0577 | 0 0173 | ****** | 0 069 | ****** |
| 3 | 0 0416 | 0 0176 | 0 9124 | 0 0192 | 0 0399 | ****** | 0 158 | ****** |
| 4 | 0 0516 | 0 0068 | 0 9128 | 0 0074 | 0 0495 | ****** | 0 196 | ****** |
| 5 | 0 0652 | 0 0027 | 0 9125 | 0 0030 | 0 0626 | ****** | 0 248 | ****** |
| 6 | 0 0921 | 0 0013 | 0 9135 | 0 0015 | 0 0885 | ****** | 0 351 | ****** |
| 7 | ****** | 0 0000 | 0 9132 | 0 0000 | ******* | ****** | ******* | ****** |



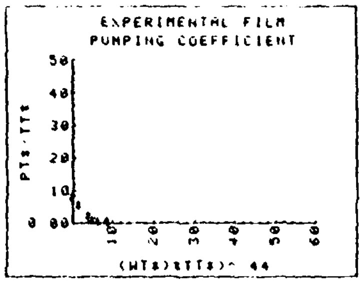




Table 10. PCD (Tertiary)

DATA TAKEN ON 17 DEC 81
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO 2 50

COMMENTS
INITIAL DATA / 3 DEG DIFFUSER

MIXING STACK INFORMATION
LENGTH 17 55 [IN]
DIAMETER 11 70 [IN]
L/D RATIO 1 50
S/D RATIO 0 50

PRIMARY NOZZLE INFORMATION
TILT ANGLE 15 0 [DEG]
ROTATION ANGLE 20 [DEG]
AREA PER NOZZLE 10 752 [IN2]
NUMBER OF NOZZLES 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6 302 [IN]
ORIFICE BETA 0 497
UPTAKE AREA 107 510 [IN2]
ATM PRESSURE 30 17 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 655 | 22 0 | 45 6 | 98 6 | 50 2 | 2 00 | 3 47 | 0 01 | 0 000 | ******* |
| 2 | 0 655 | 21 9 | 45 8 | 99 0 | 50 6 | 3 00 | 2 42 | 0 01 | 12 566 | ******* |
| 3 | 0 660 | 22 0 | 46 0 | 99 2 | 50 0 | 4 45 | 1 77 | 0 01 | 25 133 | ******* |
| 4 | 0 655 | 22 0 | 47 0 | 99 8 | 51 4 | 5 10 | 1 07 | 0 01 | 50 265 | ******* |
| 5 | 0 662 | 22 0 | 47 2 | 100 2 | 52 0 | 5 85 | 0 40 | 0 01 | 100 531 | ******* |
| 6 | 0 665 | 22 1 | 47 6 | 100 6 | 52 4 | 6 00 | 0 23 | 0 01 | 150 796 | ******* |
| 7 | 0 660 | 22 1 | 48 4 | 101 0 | 52 0 | 6 15 | 0 01 | 0 01 | ******* | ******* |

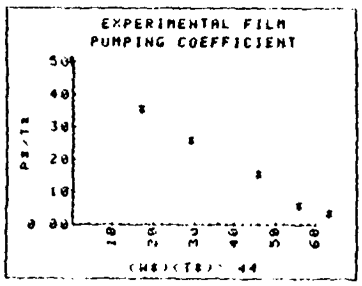
SECONDARY BOX

| N | W* | P* | T* | P* T* W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | LBM SEC | LBM SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0 0000 | 0 4607 | 0 9133 | 0 5044 | 0 0000 | 3 8039 | 0 0000 | 179 25 | 71 71 | 71 71 | 0 062 |
| 2 | 0 1796 | 0 3243 | 0 9134 | 0 3551 | 0 1726 | 3 7945 | 0 6815 | 178 48 | 83 04 | 71 40 | 0 062 |
| 3 | 0 3065 | 0 2369 | 0 9134 | 0 2594 | 0 2945 | 3 8024 | 1 1655 | 178 63 | 91 37 | 71 46 | 0 062 |
| 4 | 0 4768 | 0 1439 | 0 9135 | 0 1575 | 0 4582 | 3 7986 | 1 8112 | 178 34 | 102 33 | 71 34 | 0 062 |
| 5 | 0 5828 | 0 0540 | 0 9139 | 0 0590 | 0 5602 | 3 7978 | 2 2136 | 178 14 | 109 18 | 71 26 | 0 061 |
| 6 | 0 6615 | 0 0309 | 0 9140 | 0 0338 | 0 6358 | 3 8043 | 2 5160 | 178 52 | 114 56 | 71 42 | 0 062 |
| 7 | ****** | 0 0013 | 0 9140 | 0 0015 | ****** | 3 8020 | 2 7308 | 178 42 | ****** | 71 37 | 0 061 |

Table 10. PCD (Secondary)

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM LBM/SEC | WT LBM/SEC | UE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | ****** | 0 0013 | 0 9133 | 0 0015 | ******* | 3 804 | ******* | ****** |
| 2 | ****** | 0 0013 | 0 9134 | 0 0015 | ******* | 4 476 | ******* | ****** |
| 3 | ****** | 0 0013 | 0 9134 | 0 0015 | ******* | 4 968 | ******* | ****** |
| 4 | ****** | 0 0013 | 0 9135 | 0 0015 | ******* | 5 618 | ******* | ****** |
| 5 | ****** | 0 0013 | 0 9139 | 0 0015 | ******* | 6 011 | ******* | ****** |
| 6 | ****** | 0 0013 | 0 9140 | 0 0015 | ******* | 6 322 | ******* | ****** |
| 7 | ****** | 0 0013 | 0 9140 | 0 0015 | ******* | ****** | ******* | ****** |



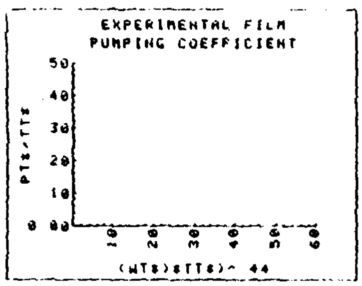




Table 10. PCD (Secondary)

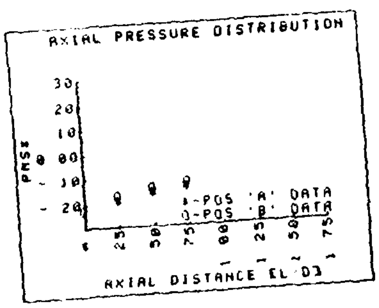
MIXING STACK DATA FOR RUN 7

TOP (POSITION 'A') DATA:

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0 00 | -2 700 | 0 | -0 364 |
| 0 25 | -1 430 | 21 | -0 193 |
| 0 50 | -1 210 | 21 | -0 163 |
| 0 75 | -1 050 | 25 | -0 141 |

DIAGONAL (POSITION 'B') DATA:

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0 00 | -1 650 | 0 | -0 222 |
| 0 25 | -1 280 | 21 | -0 172 |
| 0 50 | -1 090 | 21 | -0 147 |
| 0 75 | -0 900 | 25 | -0 121 |



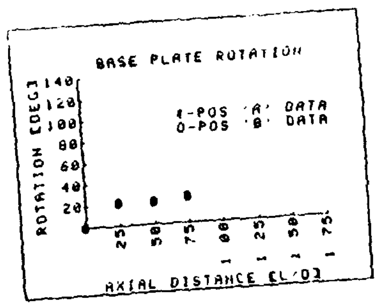
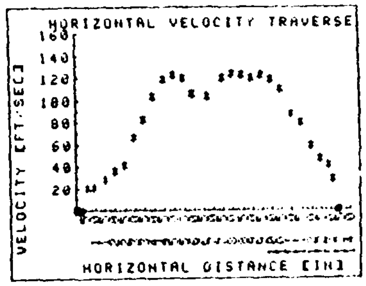




Table 10. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 10 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0 00 | 0 20 | 0 40 | 0 60 | 1 00 | 1 50 | 2 00 |
| P[IN H2O] | 0 00 | 0 00 | 0 00 | 0 10 | 0 10 | 0 20 | 0 30 |
| V[FT SEC] | 0 00 | 0 00 | 0 00 | 20 71 | 20 71 | 29 28 | 35 87 |
| POSIT[IN] | 2 50 | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5 50 |
| P[IN H2O] | 0 40 | 1 00 | 1 60 | 2 50 | 3 30 | 3 50 | 3 40 |
| V[FT/SEC] | 41 41 | 65 40 | 82 83 | 103 53 | 118 95 | 122 50 | 120 74 |
| POSIT[IN] | 6 00 | 6 75 | 7 50 | 8 00 | 8 50 | 9 00 | 9 50 |
| P[IN H2O] | 2 60 | 2 50 | 3 40 | 3 60 | 3 50 | 3 40 | 3 50 |
| V[FT/SEC] | 105 58 | 103 53 | 120 74 | 124 24 | 122 50 | 120 74 | 122 50 |
| POSIT[IN] | 10 00 | 10 50 | 11 00 | 11 50 | 12 00 | 12 50 | 12 90 |
| P[IN H2O] | 3 30 | 2 80 | 1 60 | 1 50 | 0 80 | 0 50 | 0 40 |
| V[FT SEC] | 118 95 | 109 57 | 87 85 | 80 20 | 58 57 | 46 30 | 41 41 |
| POSIT[IN] | 13 10 | 13 30 | 13 50 | | | | |
| P[IN H2O] | 0 20 | 0 00 | 0 00 | | | | |
| V[FT/SEC] | 29 28 | 0 00 | 0 00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 10 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0 00 | 0 20 | 0 40 | 0 60 | 1 00 | 1 50 | 2 00 |
| P[IN H2O] | 0 00 | 1 10 | 1 70 | 2 10 | 3 50 | 4 30 | 4 00 |
| V[FT SEC] | 0 00 | 60 68 | 65 38 | 94 89 | 122 50 | 135 78 | 130 96 |
| POSIT[IN] | 2 50 | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5\ 50 |
| P[IN H2O] | 3 60 | 2 90 | 2 80 | 3 00 | 3 20 | 3 60 | 3 30 |
| V[FT SEC] | 124 24 | 111 51 | 109 57 | 113 42 | 117 14 | 124 24 | 118 95 |
| POSIT[IN] | 6 00 | 6 75 | 7 50 | 8 00 | 8 50 | 9 00 | 9 50 |
| P[IN H2O] | 2 60 | 2 50 | 3 50 | 3 60 | 3 60 | 3 00 | 2 90 |
| V[FT SEC] | 105 58 | 103 53 | 122 50 | 127 65 | 124 24 | 113 42 | 111 51 |
| POSIT[IN] | 10 00 | 10 50 | 11 00 | 11 50 | 12 00 | 12 50 | 12 90 |
| P[IN H2O] | 3 00 | 3 30 | 4 00 | 4 30 | 4 10 | 2 90 | 1 40 |
| V[FT SEC] | 113 42 | 118 95 | 130 96 | 135 78 | 132 59 | 111 51 | 77 40 |
| POSIT[IN] | 13 10 | 13 30 | 13 50 | | | | |
| P[IN H2O] | 1 10 | 0 40 | 0 00 | | | | |
| V[FT/SEC] | 60 68 | 41 41 | 0 00 | | | | |

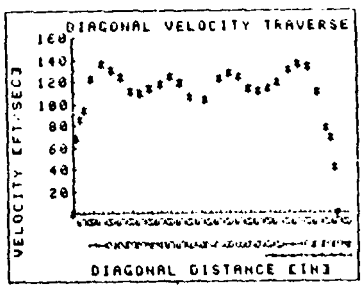



Table 10. VTD

DATA TAKEN ON 21 DEC 81
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO 2 50

COMMENTS
VERIFICATION RUN

| MIXING STACK INFORMATION | | PRIMARY NOZZLE INFORMATION | | MISCELLANEOUS INFORMATION | |
|---|---|---|---|---|---|
| LENGTH | 17 55 [IN] | TILT ANGLE | 15 0 [DEG] | ORIFICE DIAMETER | 6 902 [IN] |
| DIAMETER | 11 70 [IN] | ROTATION ANGLE | 20 [DEG] | ORIFICE BETA | 0 497 |
| L/D RATIO | 1 50 | AREA PER NOZZLE | 10 752 [IN2] | UPTAKE AREA | 107 510 [IN2] |
| S/D RATIO | 0 50 | NUMBER OF NOZZLES | 4 | ATM PRESSURE | 30 29 [INHG] |

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 670 | 22 0 | 51.4 | 102 6 | 54 8 | 6 10 | 0 01 | 0 54 | 785 000 | 0 000 |
| 2 | 0 665 | 22 0 | 51 0 | 103 0 | 55 2 | 6 10 | 0 01 | 0 39 | 785 000 | 3 142 |
| 3 | 0 670 | 22 0 | 51 2 | 103.2 | 55 4 | 6 10 | 0 01 | 0 14 | 785 000 | 12 566 |
| 4 | 0 665 | 22 0 | 51 4 | 103 4 | 55 6 | 6 10 | 0 01 | 0 06 | 785 000 | 25 133 |
| 5 | 0 670 | 22 0 | 52 2 | 103 0 | 55 6 | 6 15 | 0 01 | 0 02 | 785 000 | 50 265 |
| 6 | 0 670 | 22 0 | 51 6 | 104 0 | 55 8 | 6 10 | 0 01 | 0 01 | 785 000 | 100 531 |
| 7 | 0 665 | 22 0 | 51 6 | 104 0 | 56 0 | 6 10 | 0 01 | 0 00 | ******* | ******* |

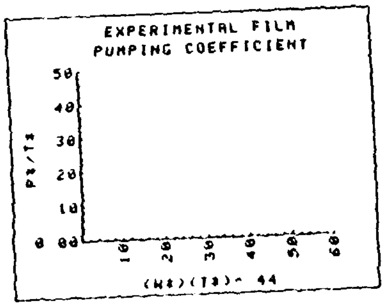
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T/ 44 | WP | WS | UP | UM | UUPT | UFT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | ****** | 0 0014 | 0 9150 | 0 0015 | ****** | 3 7897 | 2 7309 | 177 64 | ****** | 71 06 | 0 061 |
| 2 | ****** | 0 0014 | 0 9150 | 0 0015 | ****** | 3 7912 | 2 7299 | 177 84 | ****** | 71 14 | 0 061 |
| 3 | ****** | 0 0014 | 0 9151 | 0 0015 | ****** | 3 7904 | 2 7293 | 177 66 | ****** | 71 15 | 0 061 |
| 4 | ****** | 0 0014 | 0 9151 | 0 0015 | ****** | 3 7897 | 2 7288 | 177 89 | ****** | 71 16 | 0 061 |
| 5 | ****** | 0 0014 | 0 9145 | 0 0015 | ****** | 3 7867 | 2 7288 | 177 88 | ****** | 71 16 | 0 061 |
| 6 | ****** | 0 0014 | 0 9145 | 0 0015 | ****** | 3 7889 | 2 7283 | 178 05 | ****** | 71 23 | 0 061 |
| 7 | ****** | 0 0014 | 0 9148 | 0 0015 | ****** | 3 7890 | 2 7277 | 178 05 | ****** | 71 23 | 0 061 |

Table 11. Verification of Table 10 (Full Run)

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*·TT* | WT*TT^ 44 | WM LBM/SEC | WT LBM/SEC | UE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 0000 | 0 0734 | 0 9150 | 0 0802 | 0 0000 | ****** | 0 000 | ****** |
| 2 | 0 0180 | 0 0529 | 0 9150 | 0 0578 | 0 0173 | ****** | 0 068 | ****** |
| 3 | 0 0431 | 0 0190 | 0 9151 | 0 0208 | 0 0415 | ****** | 0 163 | ****** |
| 4 | 0 0565 | 0 0081 | 0 9151 | 0 0089 | 0 0543 | ****** | 0 214 | ****** |
| 5 | 0 0653 | 0 0027 | 0 9145 | 0 0030 | 0 0627 | ****** | 0 247 | ****** |
| 6 | 0 0922 | 0 0014 | 0 9145 | 0 0015 | 0 0887 | ****** | 0 349 | ****** |
| 7 | ****** | 0 0000 | 0 9148 | 0 0000 | ******* | ****** | ******* | ****** |



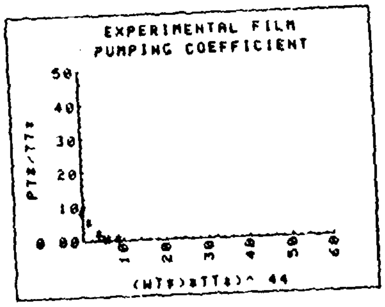




Table 11. PCD (Tertiary)

DATA TAKEN ON 21 DEC 81
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO: 2.50

COMMENTS:
VERIFICATION RUN

MIXING STACK INFORMATION:
- LENGTH: 17.55 [IN]
- DIAMETER: 11.70 [IN]
- L/D RATIO: 1.50
- S/D RATIO: 0.50

PRIMARY NOZZLE INFORMATION:
- TILT ANGLE: 15.0 [DEG]
- ROTATION ANGLE: 20 [DEG]
- AREA PER NOZZLE: 10.752 [IN2]
- NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION:
- ORIFICE DIAMETER: 6.902 [IN]
- ORIFICE BETA: 0.497
- UPTAKE AREA: 107.510 [IN2]
- ATM PRESSURE: 30.29 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0.675 | 22.1 | 52.0 | 104.4 | 56.0 | 2.90 | 3.45 | 0.00 | 0.000 | ******* |
| 2 | 0.672 | 22.0 | 51.6 | 104.2 | 56.0 | 3.00 | 2.43 | 0.00 | 12.566 | ******* |
| 3 | 0.665 | 22.0 | 51.6 | 104.4 | 56.2 | 4.40 | 1.76 | 0.00 | 25.133 | ******* |
| 4 | 0.660 | 21.9 | 52.0 | 104.0 | 56.2 | 5.20 | 1.00 | 0.00 | 50.265 | ******* |
| 5 | 0.670 | 22.1 | 51.4 | 104.6 | 56.6 | 5.85 | 0.30 | 0.00 | 100.531 | ******* |
| 6 | 0.670 | 22.0 | 52.0 | 104.0 | 56.0 | 6.00 | 0.21 | 0.00 | 150.796 | ******* |
| 7 | 0.670 | 22.0 | 51.0 | 105.0 | 57.0 | 6.15 | 0.01 | 0.00 | ******* | ******* |

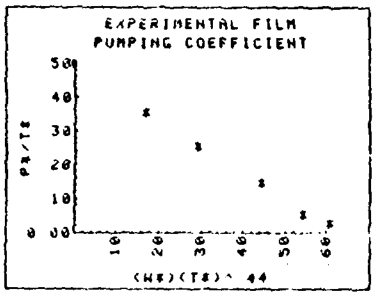
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0.0000 | 0.4575 | 0.9142 | 0.5005 | 0.0000 | 3.7960 | 0.0000 | 180.01 | 72.01 | 72.01 | 0.062 |
| 2 | 0.1796 | 0.3253 | 0.9145 | 0.3557 | 0.1727 | 3.7889 | 0.6807 | 179.16 | 83.37 | 71.67 | 0.062 |
| 3 | 0.3057 | 0.2363 | 0.9145 | 0.2584 | 0.2939 | 3.7890 | 1.1584 | 178.94 | 91.51 | 71.50 | 0.061 |
| 4 | 0.4621 | 0.1353 | 0.9139 | 0.1480 | 0.4442 | 3.7789 | 1.7463 | 178.26 | 101.35 | 71.31 | 0.061 |
| 5 | 0.5666 | 0.0511 | 0.9149 | 0.0559 | 0.5449 | 3.7983 | 2.1522 | 178.84 | 108.59 | 71.54 | 0.061 |
| 6 | 0.6335 | 0.0284 | 0.9150 | 0.0311 | 0.6092 | 3.7875 | 2.3994 | 178.32 | 112.66 | 71.33 | 0.061 |
| 7 | ****** | 0.0014 | 0.9150 | 0.0015 | ****** | 3.7882 | 2.7251 | 178.33 | ****** | 71.34 | 0.061 |

Table 11. PCD (Secondary)

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM LBM/SEC | WT LBM/SEC | UE FT-SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | ****** | 0 0000 | 0 9142 | 0 0000 | ******* | 3 796 | ******* | ****** |
| 2 | ****** | 0 0000 | 0 9145 | 0 0000 | ******* | 4 470 | ******* | ****** |
| 3 | ****** | 0 0000 | 0 9145 | 0 0000 | ******* | 4 947 | ******* | ****** |
| 4 | ****** | 0 0000 | 0 9139 | 0 0000 | ******* | 5 [illegible] | ******* | ****** |
| 5 | ****** | 0 0000 | 0 9149 | 0 0000 | ******* | 5 950 | ******* | ****** |
| 6 | ****** | 0 0000 | 0 9150 | 0 0000 | ******* | 6 187 | ******* | ****** |
| 7 | ****** | 0 0000 | 0 9150 | 0 0000 | ******* | ****** | ******* | ****** |



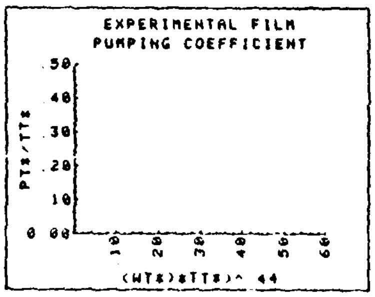




Table 11. PCD (Secondary)

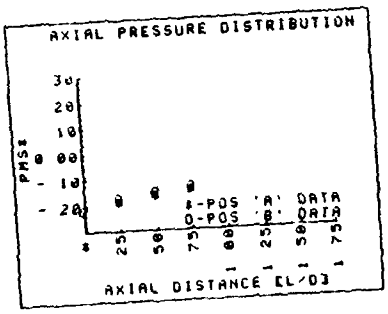
MIXING STACK DATA FOR RUN 7

TOP (POSITION 'A') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0 00 | -2 600 | 2 | -0 352 |
| 0 25 | -1 360 | 20 | -0 184 |
| 0 50 | -1 190 | 20 | -0 161 |
| 0 75 | -1 070 | 10 | -0 145 |

DIAGONAL (POSITION 'B') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
|---|---|---|---|
| 0.00 | -1 600 | 0 | -0 217 |
| 0.25 | -1 200 | 20 | -0 173 |
| 0 50 | -1 100 | 10 | -0 149 |
| 0.75 | -0 970 | 20 | 0 1[illegible] |



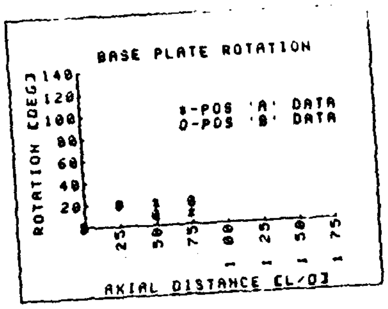
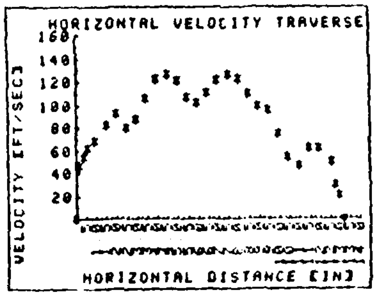




Table 11. MSD

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 85 DEGREES | | | | | | | |
| POSIT[IN] | 0 00 | 0 20 | 0 40 | 0 60 | 1 00 | 1 50 | 2 00 |
| P[IN H2O] | 0 00 | 0 50 | 0 70 | 0 90 | 1 10 | 1 60 | 2 00 |
| V[FT·SEC] | 0 00 | 46 40 | 54 90 | 62 25 | 68 82 | 83 00 | 92 00 |
| POSIT[IN] | 2 50 | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5 50 |
| P[IN H2O] | 1 50 | 1 80 | 2 60 | 3 50 | 3 70 | 3 40 | 2.70 |
| V[FT/SEC] | 80 37 | 88 04 | 105 81 | 122 76 | 126 22 | 120 99 | 107.82 |
| POSIT[IN] | 6 00 | 6 50 | 7 00 | 7 50 | 8.00 | 8 50 | 9.00 |
| P[IN H2O] | 2 40 | 2 90 | 3 40 | 3 70 | 3 50 | 2 80 | 2.30 |
| V[FT/SEC] | 101 66 | 111 74 | 120 99 | 126 22 | 122 76 | 109.80 | 99.52 |
| POSIT[IN] | 9 50 | 10 00 | 10 50 | 11 00 | 11 50 | 12.00 | 12 60 |
| P[IN H2O] | 2 10 | 1 30 | 0 70 | 0 50 | 0 90 | 0.90 | 0 60 |
| V[FT/SEC] | 95 89 | 74 82 | 54 90 | 46 40 | 62 25 | 62 25 | 50 83 |
| POSIT[IN] | 12 80 | 13 00 | 13 20 | | | | |
| P[IN H2O] | 0 20 | 0 10 | 0 00 | | | | |
| V[FT.SEC] | 29 35 | 20 75 | 0 00 | | | | |




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 85 DEGREES | | | | | | | |
| POSIT[IN] | 0 00 | 0 20 | 0 40 | 6 66 | 1 00 | 1 50 | 2 00 |
| P[IN H2O] | 0 00 | 1 10 | 1 90 | 2 50 | 4 00 | 4 50 | 4 70 |
| V[FT·SEC] | 0 00 | 60 82 | 90 45 | 103 75 | 131 24 | . 9 20 | 142.26 |
| POSIT[IN] | 2 50 | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5 50 |
| P[IN H2O] | 4 70 | 4 40 | 4 10 | 3 90 | 3 60 | 3.10 | 2.50 |
| V[FT·SEC] | 142 26 | 137 64 | 132 87 | 129 59 | 124 50 | 115.53 | 103 75 |
| POSIT[IN] | 6 00 | 6 50 | 7 00 | 7 50 | 8 00 | 8 50 | 9.00 |
| P[IN H2O] | 2 50 | 3 00 | 3 50 | 3 50 | 3.20 | 2 70 | 2.60 |
| V[FT/SEC] | 103 75 | 113 65 | 122 76 | 122.76 | 117 38 | 107.82 | 105 81 |
| POSIT[IN] | 9 50 | 10 00 | 10 50 | 11.00 | 11 50 | 12 00 | 12.60 |
| P[IN H2O] | 2 80 | 3 10 | 3.60 | 4.00 | 3 90 | 3.20 | 2 00 |
| V[FT·SEC] | 109 80 | 115.53 | 124 50 | 131.24 | 129 59 | 117.30 | 92 00 |
| POSIT[IN] | 12 60 | 13 00 | 13.20 | | | | |
| P[IN H2O] | 1 40 | 0 80 | 0 00 | | | | |
| V[FT/SEC] | 77 64 | 58 69 | 0 00 | | | | |

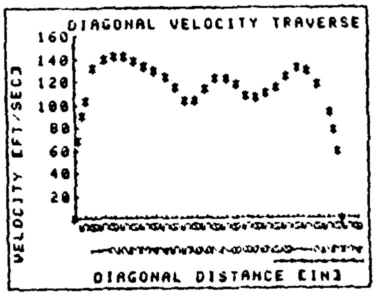



Table 11. VTD

DATA TAKEN ON: 24 DEC 81
DATA TAKEN BY  DRUCKER    NOZZLE AM/AP AREA RATIO:  2 50

COMMENTS:
7.3 DEG DIFFUSER/SLOTS OPEN

MIXING STACK INFORMATION
LENGTH  17 55 [IN]
DIAMETER:  11 70 [IN]
L/D RATIO  1 50
S/D RATIO  0 50

PRIMARY NOZZLE INFORMATION:
TILT ANGLE  15.0 [DEG]
ROTATION ANGLE:  20 [DEG]
AREA PER NOZZLE: 10 752 [IN2]
NUMBER OF NOZZLES:  4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER:  6 902 [IN]
ORIFICE BETA:  0 497
UPTAKE AREA  107 510 [IN2]
ATM PRESSURE:  30.23 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 655 | 22 0 | 39 8 | 92 2 | 45 6 | 6 15 | 0 01 | 0 50 | 785 000 | 0 000 |
| 2 | 0 655 | 22 0 | 39 6 | 92 4 | 46 4 | 6 15 | 0 01 | 0 42 | 785 000 | 3 142 |
| 3 | 0 655 | 22 0 | 39 8 | 93 0 | 46 4 | 6 15 | 0 01 | 0.17 | 785 000 | 12 566 |
| 4 | 0 655 | 22 0 | 39 6 | 93 0 | 46 6 | 6 15 | 0 01 | 0 08 | 785 000 | 25 133 |
| 5 | 0 655 | 22 0 | 39 4 | 93 0 | 46.6 | 6 15 | 0 01 | 0 03 | 785.000 | 50 265 |
| 6 | 0 655 | 22 0 | 39 4 | 93 0 | 46 8 | 6 15 | 0 01 | 0.01 | 785.000 | 100 531 |
| 7 | 0 655 | 22 0 | 39 6 | 93 2 | 47 0 | 6 15 | 0 01 | 0 01 | ******* | ******* |

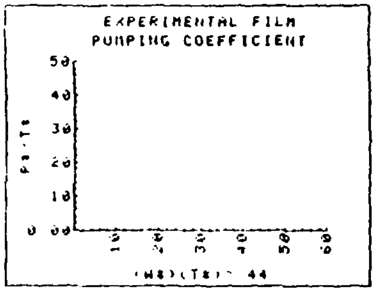
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | ****** | 0 0014 | 0 9156 | 0 0015 | ****** | 3 8297 | 2 7529 | 176 55 | ****** | 70 62 | 0 061 |
| 2 | ****** | 0 0014 | 0 9167 | 0 0015 | ****** | 3 9705 | 2 7508 | 176 64 | ****** | 70 66 | 0 061 |
| 3 | ****** | 0 0014 | 0 9157 | 0 0015 | ****** | 3 8297 | 2 7508 | 176 80 | ****** | 70 73 | 0 061 |
| 4 | ****** | 0 0014 | 0 9160 | 0 0015 | ****** | 3 8305 | 2 7502 | 176 84 | ****** | 70 74 | 0 061 |
| 5 | ****** | 0 0014 | 0 9160 | 0 0015 | ****** | 3 8312 | 2 7502 | 176 87 | ****** | 70 76 | 0 061 |
| 6 | ****** | 0 0014 | 0 9164 | 0 0015 | ****** | 3 8312 | 2 7497 | 176 87 | ****** | 70 76 | 0 061 |
| 7 | ****** | 0 0014 | 0 9164 | 0 0015 | ****** | 3 8305 | 2 7491 | 176 90 | ****** | 70 77 | 0 061 |

Table 12.  Slots Open

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | WM LBM/SEC | WT LBM/SEC | UE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.0000 | 0.0677 | 0.9156 | 0.0739 | 0.0000 | ****** | 0.000 | ****** |
| 2 | 0.0196 | 0.0569 | 0.9167 | 0.0620 | 0.0179 | ****** | 0.071 | ****** |
| 3 | 0.0474 | 0.0230 | 0.9157 | 0.0251 | 0.0456 | ****** | 0.102 | ****** |
| 4 | 0.0650 | 0.0100 | 0.9160 | 0.0110 | 0.0626 | ****** | 0.249 | ****** |
| 5 | 0.0727 | 0.0034 | 0.9160 | 0.0037 | 0.0699 | ****** | 0.278 | ****** |
| 6 | 0.0919 | 0.0014 | 0.9164 | 0.0015 | 0.0884 | ****** | 0.352 | ****** |
| 7 | ****** | 0.0007 | 0.9164 | 0.0007 | ******* | ****** | ******* | ****** |



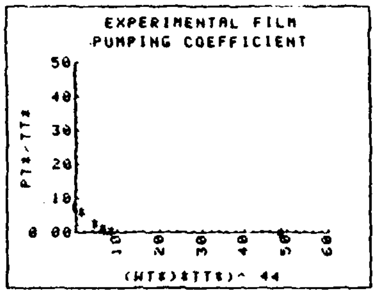




Table 12. PCD (Tertiary)

DATA TAKEN ON 24 DEC 81
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO 2.50

COMMENTS:
7.3 DEG DIFFUSER/SLOTS OPEN

MIXING STACK INFORMATION:
LENGTH 17.55 [IN]
DIAMETER 11.70 [IN]
L/D RATIO: 1.50
S/D RATIO: 0.50

PRIMARY NOZZLE INFORMATION:
TILT ANGLE: 15.0 [DEG]
ROTATION ANGLE: 20 [DEG]
AREA PER NOZZLE: 10.752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6.902 [IN]
ORIFICE BETA: 0.497
UPTAKE AREA: 107.510 [IN2]
ATM PRESSURE: 30.23 [INHG]

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0.660 | 22.0 | 39.4 | 93.2 | 47.2 | 2.90 | 3.45 | 0.00 | 0.000 | ******* |
| 2 | 0.655 | 22.0 | 39.6 | 93.2 | 47.2 | 3.90 | 2.42 | 0.00 | 12.566 | ******* |
| 3 | 0.655 | 22.0 | 40.0 | 93.6 | 47.4 | 4.50 | 1.74 | 0.00 | 25.133 | ******* |
| 4 | 0.655 | 22.0 | 40.0 | 93.8 | 47.0 | 5.30 | 0.97 | 0.00 | 50.265 | ******* |
| 5 | 0.655 | 22.0 | 40.0 | 94.0 | 47.0 | 5.85 | 0.37 | 0.00 | 100.531 | ******* |
| 6 | 0.655 | 21.9 | 40.2 | 94.2 | 48.0 | 6.00 | 0.21 | 0.00 | 150.796 | ******* |
| 7 | 0.655 | 22.1 | 40.2 | 94.2 | 48.4 | 6.20 | 0.01 | 0.00 | ******* | ******* |

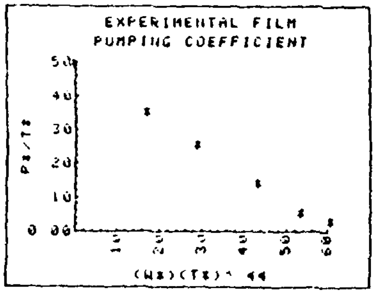
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | 0.0000 | 0.4587 | 0.9168 | 0.5003 | 0.0000 | 3.8312 | 0.0000 | 178.43 | 71.38 | 71.38 | 0.062 |
| 2 | 0.1737 | 0.3235 | 0.9168 | 0.3528 | 0.1720 | 3.8305 | 0.6845 | 177.94 | 82.77 | 71.18 | 0.062 |
| 3 | 0.3031 | 0.2333 | 0.9165 | 0.2546 | 0.2917 | 3.8289 | 1.1606 | 177.71 | 90.75 | 71.09 | 0.062 |
| 4 | 0.4524 | 0.1306 | 0.9169 | 0.1424 | 0.4355 | 3.8289 | 1.7323 | 177.44 | 100.35 | 70.98 | 0.062 |
| 5 | 0.5583 | 0.0499 | 0.9166 | 0.0545 | 0.5378 | 3.8289 | 2.1399 | 177.24 | 107.19 | 70.90 | 0.061 |
| 6 | 0.6330 | 0.0285 | 0.9166 | 0.0311 | 0.6092 | 3.8195 | 2.4177 | 176.80 | 111.74 | 70.73 | 0.061 |
| 7 | ****** | 0.0013 | 0.9173 | 0.0015 | ****** | 3.8369 | 2.7453 | 177.52 | ****** | 71.01 | 0.062 |

Table 12. PCD (Secondary)

TERTIARY BOX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | WM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC |
| 1 | ****** | 0 0000 | 0 9168 | 0 0000 | ******* | 3 831 | ******* | ****** |
| 2 | ****** | 0 0000 | 0 9168 | 0 0000 | ******* | 4 515 | ******* | ****** |
| 3 | ****** | 0 0000 | 0 9165 | 0 0000 | ******* | 4 990 | ******* | ****** |
| 4 | ****** | 0 0000 | 0 9169 | 0 0000 | ******* | 5 561 | ******* | ****** |
| 5 | ****** | 0 0000 | 0 9166 | 0 0000 | ******* | 5 969 | ******* | ****** |
| 6 | ****** | 0 0000 | 0 9166 | 0 0000 | ******* | 6.237 | ******* | ****** |
| 7 | ****** | 0 0000 | 0 9173 | 0 0000 | ******* | ****** | ******* | ****** |



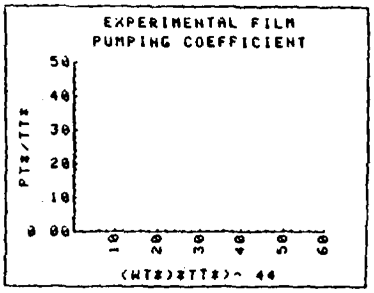




Table 12. PCD (Secondary)

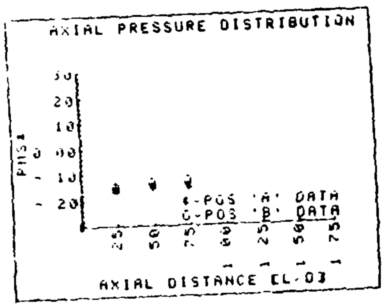
MIXING STACK DATA FOR RUN ?

TOP (POSITION 'A') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PHS* |
|---|---|---|---|
| 0 00 | -2 200 | 0 | -0 256 |
| 0 25 | -1 170 | 0 | -0 158 |
| 0 50 | -1 090 | 10 | -0 147 |
| 0 75 | -1 060 | 0 | -0 143 |

DIAGONAL (POSITION 'B') DATA

| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PHS* |
|---|---|---|---|
| 0 00 | -1 450 | 5 | -0 195 |
| 0 25 | -1 130 | 10 | -0 152 |
| 0 50 | -1 000 | 0 | -0 135 |
| 0 75 | -0 940 | 20 | -0 127 |



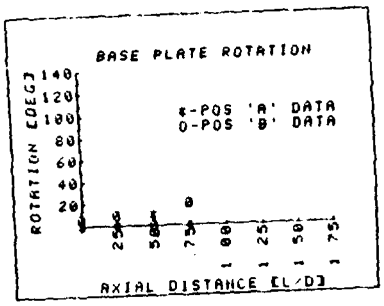
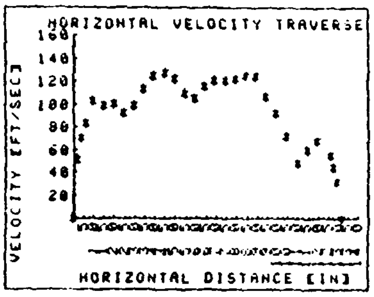




Table 12. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 85 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0 00 | 0 20 | 0 40 | 0 60 | 1 00 | 1 50 | 2 00 |
| P[IN H2O] | 0 00 | 0 65 | 1 20 | 1 65 | 2 53 | 2 35 | 2 40 |
| V[FT SEC] | 0 00 | 52 51 | 71 35 | 83 67 | 103 60 | 93 85 | 100 91 |
| POSIT[IN] | 2 50 | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5 50 |
| P[IN H2O] | 2 05 | 2 34 | 3 05 | 3 70 | 3 84 | 3 50 | 2 83 |
| V[FT/SEC] | 93 26 | 99 64 | 113 75 | 125 29 | 127 64 | 123 24 | 109 57 |
| POSIT[IN] | 6 00 | 6 50 | 7 00 | 7 50 | 8 00 | 8 50 | 9 00 |
| P[IN H2O] | 2 65 | 3 18 | 3.40 | 3 45 | 3 56 | 3.70 | 3 70 |
| V[FT/SEC] | 106 03 | 116 15 | 121 51 | 120 98 | 123 24 | 125 29 | 125 29 |
| POSIT[IN] | 9 50 | 10 00 | 10 50 | 11 00 | 11 50 | 12 00 | 12 60 |
| P[IN H2O] | 2 73 | 2 05 | 1 25 | 0 58 | 0 88 | 1.10 | 0 72 |
| V[FT SEC] | 107 62 | 93 26 | 72 82 | 49 60 | 61.10 | 68 31 | 55 27 |
| POSIT[IN] | 12 80 | 13 00 | 13 20 | | | | |
| P[IN H2O] | 0 50 | 0 25 | 0 00 | | | | |
| V[FT/SEC] | 46 06 | 32 57 | 0 00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 85 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0 00 | 0 20 | 0 40 | 0 60 | 1 00 | 1 50 | 2 00 |
| P[IN H2O] | 0 00 | 1 00 | 1 84 | 2 22 | 3 24 | 4 02 | 4 25 |
| V[FT SEC] | 0 00 | 65 13 | 88 35 | 97 05 | 117 34 | 130 59 | 134 28 |
| POSIT[IN] | 2 50 | 3 00 | 3 50 | 4 00 | 4 50 | 5 00 | 5 50 |
| P[IN H2O] | 4 30 | 4 35 | 4 40 | 4 37 | 4 24 | 3.90 | 3 37 |
| V[FT SEC] | 135 07 | 135 85 | 136 63 | 136 16 | 134 12 | 128 63 | 119 57 |
| POSIT[IN] | 6 00 | 6 50 | 7 00 | 7 50 | 8 00 | 8 50 | 9 00 |
| P[IN H2O] | 3 02 | 3 20 | 3 57 | 3 92 | 4 05 | 3 82 | 3.20 |
| V[FT SEC] | 113 19 | 116 52 | 123 07 | 128 96 | 131 08 | 127 30 | 116 52 |
| POSIT[IN] | 9 50 | 10 00 | 10 50 | 11 00 | 11 50 | 12 00 | 12 60 |
| P[IN H2O] | 3 55 | 3 70 | 3 90 | 3 84 | 3 58 | 2 74 | 1 60 |
| V[FT SEC] | 122 72 | 125 29 | 128 63 | 127 64 | 123 24 | 107 82 | 82 39 |
| POSIT[IN] | 12 80 | 13 00 | 13 20 | | | | |
| P[IN H2O] | 1 15 | 0 75 | 0 05 | | | | |
| V[FT/SEC] | 69 85 | 56 41 | 14 56 | | | | |

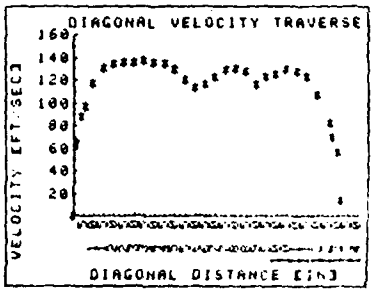



Table 12. VTD

DATA TAKEN ON 6 JAN 92
DATA TAKEN BY DRUCKER

NOZZLE AN NP AREA RATIO 2 50

COMMENTS
VERIFICATION 7 3 DIFF SLOTS OPN

MIXING STACK INFORMATION
LENGTH 17 55 [IN]
DIAMETER 11 70 [IN]
L D RATIO 1 50
S D RATIO 0 50

PRIMARY NOZZLE INFORMATION
TILT ANGLE 15 0 [DEG]
ROTATION ANGLE: 20 [DEG]
AREA PER NOZZLE: 10 752 [IN2]
NUMBER OF NOZZLES: 4

MISCELLANEOUS INFORMATION
ORIFICE DIAMETER 6 982 [IN]
ORIFICE BETA: 0 497
UPTAKE AREA: 107 510 [IN2]
ATM PRESSURE: 30 27 [INHG]

| N | PUR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H2O | | DEGREES F | | | IN OF H2O | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 655 | 22 0 | 39 4 | 92 6 | 50 2 | 6 20 | 0 01 | 0 60 | 785 000 | 0 000 |
| 2 | 0 655 | 22 0 | 39 4 | 93 0 | 50 4 | 6 15 | 0 01 | 0 46 | 785 000 | 3 142 |
| 3 | 0 655 | 22 1 | 39 2 | 93 0 | 50 4 | 6 20 | 0 01 | 0 18 | 785 000 | 12 566 |
| 4 | 0 655 | 22 1 | 39 0 | 93 2 | 50 6 | 6 20 | 0 01 | 0 07 | 785 000 | 25 133 |
| 5 | 0 655 | 22 1 | 39 0 | 93 0 | 50 6 | 6 20 | 0 01 | 0 03 | 785 000 | 50 265 |
| 6 | 0 655 | 22 1 | 36 6 | 93 0 | 50 8 | 6 20 | 0 01 | 0 01 | 785 000 | 100 531 |
| 7 | 0 655 | 22 1 | 38 8 | 93 0 | 50 8 | 6 20 | 0 01 | 0 01 | ******* | ******* |

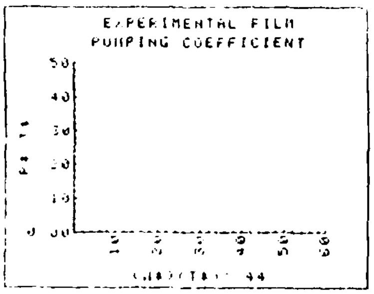
SECONDARY BOX

| N | W* | P* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM/SEC | LBM/SEC | FT/SEC | FT/SEC | FT/SEC | |
| 1 | ****** | 0 0014 | 0 9232 | 0 0015 | ****** | 3 8338 | 2 7423 | 176 63 | ****** | 70 66 | 0 061 |
| 2 | ****** | 0 0014 | 0 9229 | 0 0015 | ****** | 3 8339 | 2 7418 | 176 76 | ****** | 70 71 | 0 061 |
| 3 | ****** | 0 0014 | 0 9229 | 0 0015 | ****** | 3 8433 | 2 7418 | 177 19 | ****** | 70 88 | 0 062 |
| 4 | ****** | 0 0014 | 0 9229 | 0 0015 | ****** | 3 8440 | 2 7412 | 177 29 | ****** | 70 92 | 0 062 |
| 5 | ****** | 0 0014 | 0 9233 | 0 0015 | ****** | 3 8440 | 2 7412 | 177 23 | ****** | 70 90 | 0 062 |
| 6 | ****** | 0 0014 | 0 9236 | 0 0015 | ****** | 3 3456 | 2 7407 | 177 30 | ****** | 70 93 | 0 062 |
| 7 | ****** | 0 0014 | 0 9236 | 0 0015 | ****** | 3 8448 | 2 7407 | 177 26 | ****** | 70 91 | 0 062 |

Table 13. Verification of Table 12 (Full Run)

TERTIARY COX

| N | WT* | PT* | TT* | PT*/TT* | WT*TT^.44 | UM | WT | UE |
|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM SEC | LBM/SEC | FT SEC |
| 1 | 0 0000 | 0 0618 | 0 9232 | 0 0886 | 0 0000 | ****** | 0 000 | ****** |
| 2 | 0 0194 | 0 0626 | 0 9229 | 0 0679 | 0 0137 | ****** | 0 074 | ****** |
| 3 | 0 0485 | 0 0244 | 0 9229 | 0 0264 | 0 0468 | ****** | 0 186 | ****** |
| 4 | 0 0604 | 0 0035 | 0 9229 | 0 0103 | 0 0583 | ****** | 0 232 | ****** |
| 5 | 0 0791 | 0 0041 | 0 9233 | 0 0044 | 0 0764 | ****** | 0 304 | ****** |
| 6 | 0 0913 | 0 0014 | 0 9236 | 0 0015 | 0 0881 | ****** | 0 351 | ****** |
| 7 | ****** | 0 0007 | 0 9236 | 0 0007 | ******* | ****** | ******* | ****** |



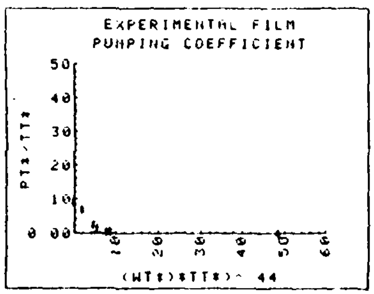




Table 13. PCD (Tertiary)

DATA TAKEN ON 6 JAN 82
DATA TAKEN BY DRUCKER

NOZZLE AM/AP AREA RATIO 2 50

COMMENTS
VERIFICATION 7 3 DIFF/SLOTS OPN

| MIXING STACK INFORMATION | | PRIMARY NOZZLE INFORMATION | | MISCELLANEOUS INFORMATION | |
|---|---|---|---|---|---|
| LENGTH | 17 55 [IN] | TILT ANGLE | 15 0 [DEG] | ORIFICE DIAMETER | 6 902 [IN] |
| DIAMETER | 11 70 [IN] | ROTATION ANGLE | 20 [DEG] | ORIFICE BETA | 0 497 |
| L/D RATIO | 1 50 | AREA PER NOZZLE | 10 752 [IN2] | UPTAKE AREA | 107 510 [IN2] |
| S/D RATIO | 0 50 | NUMBER OF NOZZLES | 4 | ATM PRESSURE | 30 27 [INHG] |

| N | POR | DPOR | TOR | TUPT | TAMB | PUPT | PSEC | PTER | SECONDARY AREA | TERTIARY AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| RUN | IN OF H20 | | DEGREES F | | | IN OF H20 | | | SQUARE INCHES | SQUARE INCHES |
| 1 | 0 655 | 22 1 | 37 8 | 92 8 | 50 6 | 2 90 | 3 45 | 0 01 | 0 000 | ******* |
| 2 | 0 650 | 22 0 | 38 2 | 92 8 | 50 6 | 3 85 | 2 44 | 0 01 | 12 566 | ******* |
| 3 | 0 650 | 22 0 | 38 0 | 92 6 | 51 0 | 4 50 | 1 80 | 0 01 | 25 133 | ******* |
| 4 | 0 650 | 22 0 | 38 0 | 92 8 | 50 8 | 5 25 | 1 00 | 0 01 | 50 265 | ******* |
| 5 | 0 645 | 21 9 | 38 6 | 92 8 | 51 0 | 5 80 | 0 38 | 0 01 | 100 531 | ******* |
| 6 | 0 655 | 22 1 | 38 2 | 93 0 | 51 2 | 6 05 | 0 22 | 0 01 | 150 796 | ******* |
| 7 | 0 655 | 22 1 | 38 0 | 93 0 | 51 4 | 6 20 | 0 01 | 0 01 | ******* | ******* |

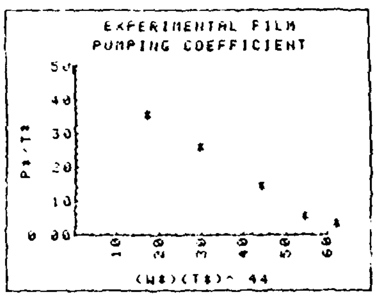
SECONDARY BOX

| N | W* | F* | T* | P*/T* | W*T^.44 | WP | WS | UP | UM | UUPT | UPT MACH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RUN | | | | | | LBM SEC | LBM SEC | FT SEC | FT SEC | FT SEC | |
| 1 | 0 0000 | 0 4523 | 0 9276 | 0 4368 | 0 0000 | 3 8487 | 0 0000 | 178 87 | 71 55 | 71 56 | 0 062 |
| 2 | 0 1735 | 0 2273 | 0 9276 | 0 3550 | 0 1724 | 3 8384 | 0 6854 | 177 96 | 82 36 | 71 19 | 0 062 |
| 3 | 0 3066 | 0 2429 | 0 9247 | 0 2627 | 0 2962 | 3 8392 | 1 1770 | 177 65 | 91 12 | 71 07 | 0 062 |
| 4 | 0 4571 | 0 1353 | 0 9240 | 0 1464 | 0 4415 | 3 8392 | 1 7549 | 177 37 | 100 85 | 70 95 | 0 062 |
| 5 | 0 5651 | 0 0519 | 0 9243 | 0 0561 | 0 5458 | 3 8282 | 2 1632 | 176 59 | 107 50 | 70 64 | 0 061 |
| 6 | 0 6416 | 0 0298 | 0 9244 | 0 0322 | 0 6198 | 3 8471 | 2 4684 | 177 46 | 113 07 | 70 95 | 0 062 |
| 7 | ****** | 0 0014 | 0 9247 | 0 0015 | ****** | 3 8479 | 2 7391 | 177 41 | ****** | 70 97 | 0 062 |

Table 13. PCD (Secondary)

TERTIARY BOX

| N RUN | WT* | PT* | TT* | PT*/TT* | WT*TT^ 44 | WM LBM/SEC | WT LBM/SEC | UE FT/SEC |
|---|---|---|---|---|---|---|---|---|
| 1 | ******* | 0 0007 | 0 9236 | 0 0007 | ******** | 3 849 | ******** | ****** |
| 2 | ******* | 0 0007 | 0 9236 | 0 0007 | ******** | 4 524 | ******** | ****** |
| 3 | ******* | 0 0007 | 0 9247 | 0 0007 | ******** | 5 016 | ******** | ****** |
| 4 | ******* | 0 0007 | 0 9240 | 0 0007 | ******** | 5 594 | ******** | ****** |
| 5 | ******* | 0 0007 | 0 9243 | 0 0007 | ******** | 5 991 | ******** | ****** |
| 6 | ******* | 0 0007 | 0 9244 | 0 0007 | ******** | 6 316 | ******** | ****** |
| 7 | ******* | 0 0007 | 0 9247 | 0 0007 | ******** | ****** | ******** | ****** |



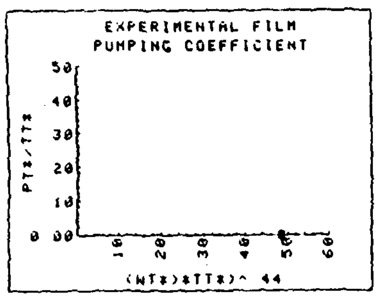
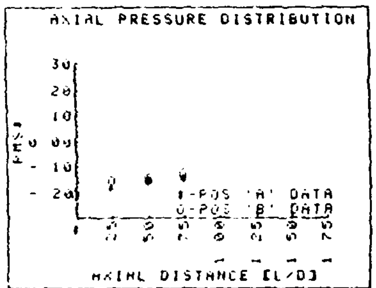




Table 13. PCD (Secondary)

MIXING STACK DATA FOR RUN 7

| TOP (POSITION 'A') DATA | | | | DIAGONAL (POSITION 'B') DATA | | | |
|---|---|---|---|---|---|---|---|
| X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* | X/D | PRESSURE [IN H2O] | ROTATION [DEG] | PMS* |
| 0 00 | -2 520 | 0 | -0 341 | 0 00 | -1 550 | 0 | -0 210 |
| 0 25 | -1 300 | 0 | -0 176 | 0 25 | -1 170 | 20 | -0 158 |
| 0 50 | -1 100 | 20 | -0 149 | 0 50 | -1 050 | 20 | -0 142 |
| 0 75 | -1 080 | 0 | -0 146 | 0 75 | -0 940 | 20 | -0 127 |



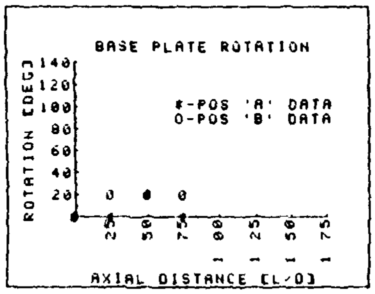
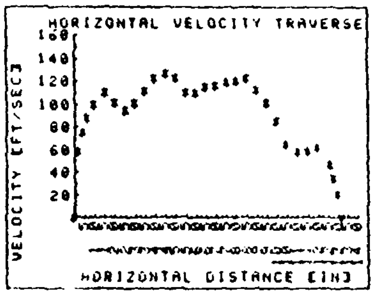




Table 13. MSD

HORIZONTAL VELOCITY TRAVERSE AT BASE ROTATION OF 85 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.40 | 0.60 | 1.00 | 1.50 | 2.00 |
| P[IN H2O] | 0.00 | 0.80 | 1.30 | 1.80 | 2.30 | 2.80 | 2.40 |
| V[FT/SEC] | 0.00 | 58.39 | 74.43 | 87.59 | 59.01 | 109.24 | 101.14 |
| POSIT[IN] | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 |
| P[IN H2O] | 2.10 | 2.40 | 2.90 | 3.50 | 3.80 | 3.50 | 2.80 |
| V[FT/SEC] | 94.60 | 101.14 | 111.17 | 122.13 | 127.26 | 122.13 | 109.24 |
| POSIT[IN] | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 |
| P[IN H2O] | 2.80 | 3.10 | 3.20 | 3.30 | 3.40 | 3.50 | 3.00 |
| V[FT/SEC] | 109.24 | 114.94 | 116.78 | 118.59 | 120.38 | 122.13 | 113.07 |
| POSIT[IN] | 9.50 | 10.00 | 10.50 | 11.00 | 11.50 | 12.00 | 12.60 |
| P[IN H2O] | 2.40 | 1.70 | 1.00 | 0.80 | 0.80 | 0.90 | 0.50 |
| V[FT/SEC] | 101.14 | 85.12 | 65.20 | 58.39 | 58.39 | 61.93 | 46.16 |
| POSIT[IN] | 12.80 | 13.00 | 13.20 | | | | |
| P[IN H2O] | 0.30 | 0.10 | 0.00 | | | | |
| V[FT/SEC] | 35.76 | 20.64 | 0.00 | | | | |




DIAGONAL VELOCITY TRAVERSE FOR BASE ROTATION OF 85 DEGREES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| POSIT[IN] | 0.00 | 0.20 | 0.40 | 0.60 | 1.00 | 1.50 | 2.00 |
| P[IN H2O] | 0.00 | 1.30 | 1.60 | 2.40 | 3.50 | 3.90 | 4.40 |
| V[FT/SEC] | 0.00 | 74.43 | 82.58 | 101.14 | 122.13 | 128.92 | 136.94 |
| POSIT[IN] | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 |
| P[IN H2O] | 4.20 | 4.00 | 4.10 | 4.20 | 4.10 | 3.80 | 3.50 |
| V[FT/SEC] | 133.79 | 130.57 | 132.19 | 133.79 | 132.19 | 127.26 | 122.13 |
| POSIT[IN] | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 |
| P[IN H2O] | 3.30 | 3.30 | 3.40 | 3.55 | 3.85 | 3.70 | 3.55 |
| V[FT/SEC] | 118.59 | 118.59 | 120.38 | 123.00 | 128.10 | 125.58 | 123.00 |
| POSIT[IN] | 9.50 | 10.00 | 10.50 | 11.00 | 11.50 | 12.00 | 12.60 |
| P[IN H2O] | 3.10 | 3.70 | 3.90 | 4.00 | 4.20 | 3.30 | 2.10 |
| V[FT/SEC] | 114.34 | 125.58 | 128.92 | 130.57 | 133.79 | 118.59 | 94.60 |
| POSIT[IN] | 12.80 | 13.00 | 13.20 | | | | |
| P[IN H2O] | 1.50 | 1.00 | 0.00 | | | | |
| V[FT/SEC] | 79.96 | 65.28 | 0.00 | | | | |

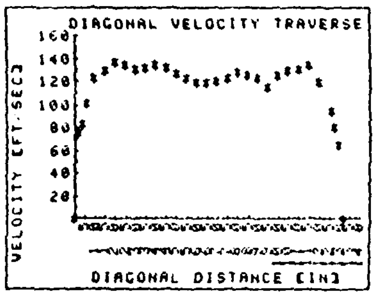



Table 13. VTD

DATA TAKEN ON 19 DEC 81
DATA TAKEN BY DRUCKER
PRIMARY NOZZLE INFORMATION:
TILT ANGLE 15.0 [DEG]
ROTATION ANGLE 20 [DEG]

COMMENTS:
0.2 INCH FM OUTER EDGE
AMB PRESSURE:30.23 [IN HG]
AMB TEMPERATURE:61.4 [DEG F]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0.0 | 5.0 | 15.0 | 25.0 | 35.0 | 45.0 | 70.0 | 80.0 | 90.0 |
| P[IN H2O] | 0.20 | 0.10 | 0.70 | 1.00 | 0.90 | 0.90 | 0.20 | 0.00 | 0.10 |
| V[FT/SEC] | 29.50 | 20.86 | 55.1 | 65.96 | 62.58 | 62.50 | 29.50 | 0.00 | 20.86 |
| PSI[DEG] | 100.0 | 110.0 | 120.0 | 130.0 | 135.0 | 140.0 | 145.0 | 150.0 | 155.0 |
| P[IN H2O] | 0.40 | 0.60 | 0.80 | 1.00 | 1.00 | 0.90 | 0.80 | 0.60 | 0.40 |
| V[FT/SEC] | 41.72 | 51.09 | 59.0 | 65.96 | 65.96 | 62.58 | 59.00 | 51.09 | 41.72 |
| PSI[DEG] | 160.0 | 165.0 | 170.0 | 175.0 | 180.0 | 185.0 | 195.0 | 205.0 | 215.0 |
| P[IN H2O] | 0.30 | 0.30 | 0.15 | 0.10 | 0.10 | 0.20 | 1.10 | 1.20 | 1.30 |
| V[FT/SEC] | 36.13 | 36.13 | 25.5 | 20.86 | 20.86 | 29.50 | 69.10 | 72.26 | 75.21 |
| PSI[DEG] | 225.0 | 250.0 | 260.0 | 270.0 | 280.0 | 290.0 | 300.0 | 310.0 | 315.0 |
| P[IN H2O] | 1.10 | 0.20 | 0.10 | 0.70 | 0.70 | 1.10 | 1.00 | 1.00 | 1.30 |
| V[FT/SEC] | 69.18 | 29.50 | 20.0 | 55.19 | 55.19 | 69.10 | 65.96 | 65.96 | 75.21 |
| PSI[DEG] | 320.0 | 325.0 | 330.0 | 335.0 | 340.0 | 345.0 | 350.0 | 355.0 | 360.0 |
| P[IN H2O] | 0.70 | 1.20 | 0.60 | 0.90 | 0.10 | 0.10 | -0.05 | 0.10 | 0.20 |
| V[FT/SEC] | 55.19 | 72.26 | 51.0 | 62.58 | 20.86 | 20.86 | -14.75 | 20.86 | 29.50 |

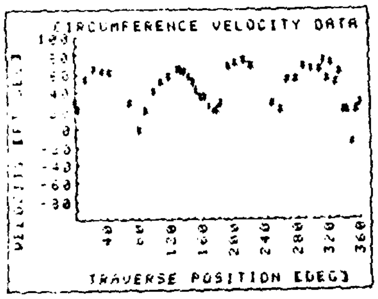



Table 14. Slots Closed

DATA TAKEN ON 19 DEC 81
DATA TAKEN BY DRUCKER
PRIMARY NOZZLE INFORMATION
TILT ANGLE 15.0 [DEG]
ROTATION ANGLE 20 [DEG]

COMMENTS:
0.5 INCH FM OUTER EDGE
AMB PRESSURE 30.23 [IN HG]
AMB TEMPERATURE 61.4 [DEG F]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0.0 | 5.0 | 15.0 | 25.0 | 35.0 | 45.0 | 70.0 | 80.0 | 90.0 |
| P[IN H2O] | 0.40 | 0.20 | 1.10 | 1.90 | 1.60 | 2.10 | 0.40 | 0.05 | 0.40 |
| V[FT SEC] | 41.72 | 29.50 | 69.1 | 90.92 | 83.44 | 95.59 | 41.72 | 14.75 | 41.72 |
| PSI[DEG] | 100.0 | 110.0 | 120.0 | 130.0 | 135.0 | 140.0 | 145.0 | 150.0 | 155.0 |
| P[IN H2O] | 1.00 | 1.20 | 1.50 | 1.60 | 2.10 | 1.40 | 1.50 | 1.30 | 1.00 |
| V[FT SEC] | 65.96 | 72.26 | 80.7 | 83.44 | 95.59 | 78.05 | 80.79 | 75.21 | 65.96 |
| PSI[DEG] | 160.0 | 165.0 | 170.0 | 175.0 | 180.0 | 185.0 | 195.0 | 205.0 | 215.0 |
| P[IN H2O] | 0.80 | 0.60 | 0.35 | 0.20 | 0.50 | 0.60 | 1.50 | 2.10 | 2.50 |
| V[FT SEC] | 59.00 | 51.09 | 39.0 | 29.50 | 46.64 | 51.09 | 80.79 | 95.59 | 104.30 |
| PSI[DEG] | 225.0 | 250.0 | 260.0 | 270.0 | 280.0 | 290.0 | 300.0 | 310.0 | 315.0 |
| P[IN H2O] | 2.20 | 0.40 | 0.30 | 0.90 | 1.40 | 2.10 | 1.80 | 2.00 | 2.50 |
| V[FT SEC] | 97.84 | 41.72 | 36.1 | 62.58 | 78.05 | 95.59 | 88.50 | 93.29 | 104.30 |
| PSI[DEG] | 320.0 | 325.0 | 330.0 | 335.0 | 340.0 | 345.0 | 350.0 | 355.0 | 360.0 |
| P[IN H2O] | 1.30 | 2.00 | 0.70 | 1.50 | 0.30 | 0.40 | 0.00 | 0.15 | 0.40 |
| V[FT SEC] | 75.21 | 93.29 | 55.1 | 80.79 | 36.13 | 41.72 | 0.00 | 25.55 | 41.72 |

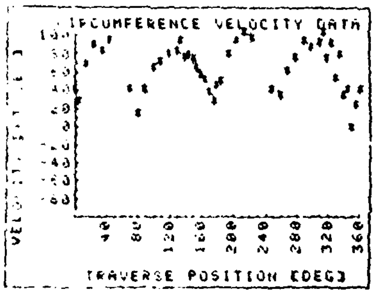



Table 14.

DATA TAKEN ON 19 DEC 81
DATA TAKEN BY CRUCKER
PRIMARY NOZZLE INFORMATION:
TILT ANGLE: 15.0 [DEG]
ROTATION ANGLE 20 [DEG]

COMMENTS:
0.9 INCH FM OUTER EDGE/SLT CLD
AMB PRESSURE: 30.23 [IN HG]
AMB TEMPERATURE: 61.4 [DEG F]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0.0 | 5.0 | 15.0 | 25.0 | 35.0 | 45.0 | 70.0 | 80.0 | 90.0 |
| P[IN H2O] | 0.80 | 0.40 | 1.70 | 2.80 | 2.70 | 2.90 | 0.90 | 0.10 | 0.50 |
| V[FT SEC] | 59.00 | 41.72 | 86.0 | 110.30 | 108.39 | 112.33 | 62.58 | 20.86 | 46.64 |
| PSI[DEG] | 100.0 | 110.0 | 120.0 | 130.0 | 135.0 | 140.0 | 145.0 | 150.0 | 155.0 |
| P[IN H2O] | 1.40 | 1.80 | 2.20 | 2.70 | 2.90 | 2.20 | 1.80 | 1.80 | 0.70 |
| V[FT SEC] | 78.05 | 88.50 | 97.0 | 108.39 | 112.33 | 97.84 | 88.50 | 88.50 | 55.19 |
| PSI[DEG] | 160.0 | 165.0 | 170.0 | 175.0 | 180.0 | 185.0 | 195.0 | 205.0 | 215.0 |
| P[IN H2O] | 1.00 | 0.70 | 0.40 | 0.40 | 0.50 | 0.80 | 2.20 | 3.00 | 3.60 |
| V[FT SEC] | 65.96 | 55.19 | 41.7 | 41.72 | 46.64 | 59.00 | 97.84 | 114.25 | 125.16 |
| PSI[DEG] | 225.0 | 250.0 | 260.0 | 270.0 | 280.0 | 290.0 | 300.0 | 310.0 | 315.0 |
| P[IN H2O] | 3.40 | 0.60 | 0.30 | 1.10 | 1.90 | 2.90 | 2.90 | 2.70 | 3.60 |
| V[FT SEC] | 121.63 | 51.09 | 36.1 | 69.18 | 90.92 | 112.33 | 112.33 | 108.39 | 125.16 |
| PSI[DEG] | 320.0 | 325.0 | 330.0 | 335.0 | 340.0 | 345.0 | 350.0 | 355.0 | 360.0 |
| P[IN H2O] | 2.00 | 3.00 | 1.40 | 1.90 | 0.60 | 0.50 | 0.10 | 0.30 | 0.80 |
| V[FT SEC] | 93.29 | 114.25 | 70.0 | 90.92 | 51.09 | 46.64 | 20.86 | 36.13 | 59.00 |

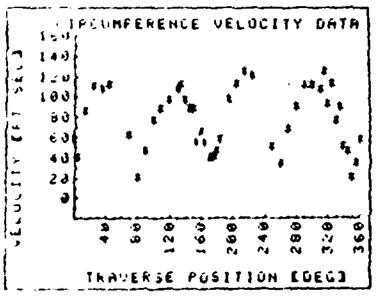



Table 14.

DATA TAKEN ON 19 DEC 81
DATA TAKEN BY DRUCKER
PRIMARY NOZZLE INFORMATION
TILT ANGLE 15.0 [DEG]
ROTATION ANGLE 20 [DEG]

COMMENTS
1.5 INCH FM OUTER EDGE/SLT CLD
AMB PRESSURE 30.23 [IN HG]
AMB TEMPERATURE 61.4 [DEG F]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0.0 | 5.0 | 15.0 | 25.0 | 35.0 | 45.0 | 70.0 | 80.0 | 90.0 |
| P[IN H2O] | 0.70 | 0.40 | 2.00 | 3.90 | 4.30 | 4.10 | 1.10 | 0.20 | 1.00 |
| V[FT/SEC] | 55.19 | 41.72 | 93.2 | 130.27 | 136.78 | 133.56 | 69.18 | 29.50 | 65.96 |
| PSI[DEG] | 100.0 | 110.0 | 120.0 | 130.0 | 135.0 | 140.0 | 145.0 | 150.0 | 155.0 |
| P[IN H2O] | 1.70 | 2.50 | 3.10 | 4.00 | 3.90 | 4.30 | 3.00 | 3.00 | 1.30 |
| V[FT/SEC] | 86.00 | 104.30 | 116.1 | 131.93 | 130.27 | 136.78 | 114.25 | 114.25 | 75.21 |
| PSI[DEG] | 160.0 | 165.0 | 170.0 | 175.0 | 180.0 | 185.0 | 195.0 | 205.0 | 215.0 |
| P[IN H2O] | 1.90 | 1.00 | 0.90 | 0.40 | 0.70 | 0.90 | 2.50 | 3.20 | 4.40 |
| V[FT/SEC] | 90.92 | 65.96 | 62.5 | 41.72 | 55.19 | 62.50 | 104.30 | 118.00 | 138.36 |
| PSI[DEG] | 225.0 | 250.0 | 260.0 | 270.0 | 280.0 | 290.0 | 300.0 | 310.0 | 315.0 |
| P[IN H2O] | 4.40 | 1.10 | 0.80 | 1.40 | 2.00 | 3.70 | 4.30 | 4.20 | 4.90 |
| V[FT/SEC] | 138.36 | 69.18 | 59.0 | 78.05 | 110.30 | 126.00 | 136.78 | 135.10 | 146.01 |
| PSI[DEG] | 320.0 | 325.0 | 330.0 | 335.0 | 340.0 | 345.0 | 350.0 | 355.0 | 360.0 |
| P[IN H2O] | 3.50 | 4.30 | 1.80 | 2.40 | 1.00 | 0.80 | 0.10 | 0.40 | 0.70 |
| V[FT/SEC] | 123.40 | 136.78 | 88.5 | 102.19 | 65.96 | 59.00 | 20.06 | 41.72 | 55.19 |

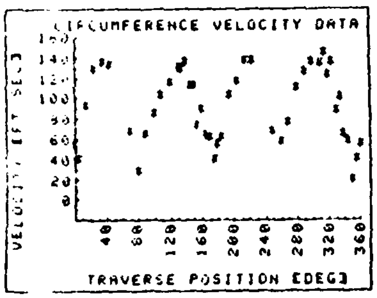



Table 14.

DATA TAKEN ON 7 JAN 82
DATA TAKEN BY DRUCKER
PRIMARY NOZZLE INFORMATION:
TILT ANGLE 15 0 [DEG]
POTATION ANGLE 20 [DEG]

COMMENTS
0 2 INCH FM OUTER EDGE
AMB PRESSURE 30 42 [IN HG]
AMB TEMPERATURE 50 6 [DEG F]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0 0 | 5 0 | 15 0 | 25 0 | 35 0 | 45 0 | 70 0 | 80 0 | 90 0 |
| P[IN H2O] | 0 15 | 0 00 | 0 40 | 0 80 | 1 10 | 1 00 | 0 20 | 0 00 | 0 00 |
| V[FT SEC] | 25 20 | 0 00 | 41 1 | 50 20 | 68 25 | 65 07 | 29 10 | 0 00 | 0 00 |
| PSI[DEG] | 100 0 | 110 0 | 120 0 | 130 0 | 135 0 | 140 0 | 145 0 | 150 0 | 155 0 |
| P[IN H2O] | 0 10 | 0 30 | 0 60 | 0 90 | 0 90 | 1 10 | 0 60 | 1 00 | 0 40 |
| V[FT/SEC] | 20 50 | 35 64 | 50 4 | 61 73 | 61 73 | 68 25 | 50 40 | 65.07 | 41 15 |
| PSI[DEG] | 160 0 | 165 0 | 170 0 | 175 0 | 180 0 | 185 0 | 195 0 | 205 0 | 215 0 |
| P[IN H2O] | 0 70 | 0 10 | 0 30 | 0 10 | 0 10 | 0.30 | 0 60 | 1 00 | 1 10 |
| V[FT SEC] | 54 44 | 20 50 | 35 6 | 20 56 | 20 50 | 35 64 | 50 40 | 65 07 | 68 25 |
| PSI[DEG] | 225 0 | 250 0 | 260 0 | 270 0 | 280 0 | 290 0 | 300 0 | 310 0 | 315 0 |
| P[IN H2O] | 1 00 | 0 20 | 0 05 | 0 40 | 1 00 | 1.10 | 1 20 | 1 30 | 1.50 |
| V[FT/SEC] | 65 07 | 29 10 | 14 5 | 41 15 | 65 07 | 68.25 | 71 20 | 74 19 | 79 70 |
| PSI[DEG] | 320 0 | 325 0 | 330 0 | 335 0 | 340 0 | 345 0 | 350.0 | 355 0 | 360.0 |
| P[IN H2O] | 1 00 | 1 50 | 0 40 | 0 80 | 0 10 | 0.30 | -0.01 | -0 02 | 0.15 |
| V[FT/SEC] | 65 07 | 79 70 | 41 1 | 50 20 | 20 50 | 35 64 | -6.51 | -9.20 | 25 20 |

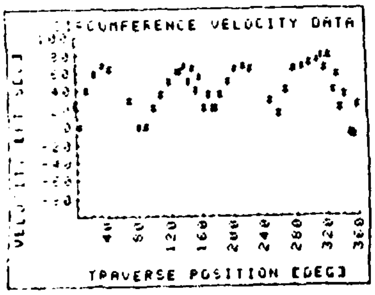



Table 15. Slots Open

DATA TAKEN ON 7 JAN 82
DATA TAKEN BY DRUCKER
PRIMARY NOZZLE INFORMATION
TILT ANGLE 15 0 [DEG]
ROTATION ANGLE 20 [DEG]

COMMENTS
0 5 INCH FM OUTER EDGE/SLT OPN
AMB PRESSURE 30 42 [IN HG]
AMB TEMPERATURE 50 6 [DEG F]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0 0 | 5 0 | 15 0 | 25 0 | 35 0 | 45 0 | 70 0 | 80 0 | 90 0 |
| P[IN H2O] | 0 50 | 0 10 | 0 70 | 1 40 | 2 00 | 1 90 | 0 60 | 0 05 | 0 10 |
| V[FT/SEC] | 46 01 | 20 58 | 54 4 | 76 99 | 92 02 | 89 69 | 50 40 | 14 55 | 20 58 |
| PSI[DEG] | 100 0 | 110 0 | 120 0 | 130 0 | 135 0 | 140 0 | 145 0 | 150 0 | 155 0 |
| P[IN H2O] | 0 40 | 0 90 | 1 50 | 1 90 | 1 40 | 1 90 | 1 20 | 1 90 | 0 60 |
| V[FT/SEC] | 41 15 | 61 73 | 79 7 | 89 69 | 76 99 | 89 69 | 71 20 | 89 69 | 50 40 |
| PSI[DEG] | 160 0 | 165 0 | 170 0 | 175 0 | 180.0 | 185 0 | 195 0 | 205 0 | 215 0 |
| P[IN H2O] | 1 10 | 0 40 | 0 40 | 0 20 | 0 30 | 0 40 | 1 10 | 1 50 | 1 70 |
| V[FT/SEC] | 60 25 | 41 15 | 41 1 | 29 10 | 35 64 | 41 15 | 68 25 | 79 70 | 84.84 |
| PSI[DEG] | 225 0 | 250 0 | 260 0 | 270 0 | 0 | 290 0 | 300 0 | 310 0 | 315.0 |
| P[IN H2O] | 1 60 | 0 40 | 0 15 | 0 90 | 4 00 | 2 30 | 2 30 | 2 20 | 2.90 |
| V[FT/SEC] | 82 31 | 41 15 | 25 2 | 61 73 | 92 02 | 98.69 | 98 69 | 96.52 | 110 81 |
| PSI[DEG] | 320 0 | 325 0 | 330 0 | 335 0 | 340 0 | 345 0 | 350 0 | 355 0 | 360 0 |
| P[IN H2O] | 1 60 | 2 10 | 0 60 | 1 20 | 0.30 | 0.50 | 0 00 | 0.00 | 0.50 |
| V[FT/SEC] | 82 31 | 94 30 | 50 4 | 71.28 | 35.64 | 46.01 | 0 00 | 0.00 | 46.01 |

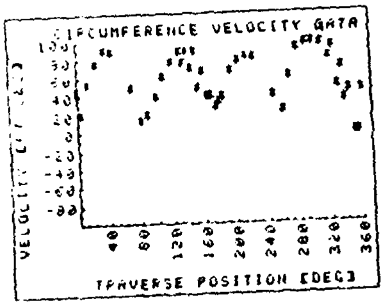



Table 15.

DATA TAKEN ON 7 JAN 82
DATA TAKEN BY DRUCKER
PRIMARY NOZZLE INFORMATION
TILT ANGLE 15 0 [DEG]
ROTATION ANGLE 20 [DEG]

COMMENTS
0 8 INCH FM OUTER EDGE/SLT OPN
AMB PRESSURE 30 42 [IN HG]
AMB TEMPERATURE 50 6 [DEG F]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0 0 | 5 0 | 15 0 | 25 0 | 35 0 | 45 0 | 70 0 | 80 0 | 90 0 |
| P[IN H2O] | 0 70 | 0 30 | 1 10 | 2 30 | 2 80 | 2 80 | 0 70 | 0 10 | 0 10 |
| V[FT SEC] | 54 44 | 35 64 | 68 2 | 98 69 | 108 88 | 108 80 | 54 44 | 20 58 | 20 53 |
| PSI[DEG] | 100 0 | 110 0 | 120 0 | 130 0 | 135 0 | 140 0 | 145 0 | 150 0 | 155 0 |
| P[IN H2O] | 0 50 | 1 30 | 2 10 | 2 60 | 2 00 | 3 00 | 1 40 | 2 80 | 1 20 |
| V[FT SEC] | 46 01 | 74 19 | 94 3 | 104 92 | 92 02 | 112 71 | 76 99 | 108 88 | 71 28 |
| PSI[DEG] | 160 0 | 165 0 | 170 0 | 17[illegible] 0 | 18[illegible] 0 | 185 0 | 195 0 | 205 0 | 215 0 |
| P[IN H2O] | 1 40 | 0 50 | 0 70 | 0 40 | 0 30 | 0 90 | 1 60 | 2 20 | 2 60 |
| V[FT SEC] | 76 99 | 46 01 | 54 4 | 41 15 | 35 64 | 61.73 | 82 31 | 96.52 | 104 92 |
| PSI[DEG] | 225 0 | 250 0 | 260 0 | 270 0 | 280 0 | 290 0 | 300 0 | 310 0 | 315 0 |
| P[IN H2O] | 2 40 | 0 50 | 0 20 | 1 20 | 2 50 | 3.30 | 3 40 | 3 00 | 4 10 |
| V[FT SEC] | 100 81 | 46 01 | 29 1 | 71 28 | 102.89 | 118.21 | 119 99 | 112 71 | 131 76 |
| PSI[DEG] | 320 0 | 325 0 | 330 0 | 335 0 | 340 0 | 345 0 | 350 0 | 355 0 | 360 0 |
| P[IN H2O] | 2 00 | 3 10 | 1 20 | 1 90 | 0.40 | 0.70 | 0.05 | 0.00 | 0 70 |
| V[FT SEC] | 92 02 | 114 57 | 71 2 | 89 69 | 41 15 | 54.44 | 14 55 | 0.00 | 54 44 |

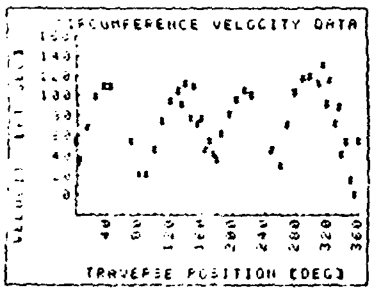



Table 15.

DATA TAKEN ON 7 JAN 82
DATA TAKEN BY DRUCKER
PRIMARY NOZZLE INFORMATION
TILT ANGLE 15.0 [DEG]
ROTATION ANGLE 20 [DEG]

COMMENTS
1.5 INCHES FM OUTER EDGE/SLT OP
AMB PRESSURE 30.42 [IN HG]
AMB TEMPERATURE 50.6 [DEG F]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PSI[DEG] | 0.0 | 5.0 | 15.0 | 25.0 | 35.0 | 45.0 | 70.0 | 80.0 | 90.0 |
| P[IN H2O] | 1.10 | 0.10 | 1.10 | 2.70 | 4.70 | 4.50 | 1.20 | 0.30 | 0.20 |
| V[FT/SEC] | 60.25 | 20.50 | 69.2 | 106.92 | 141.07 | 138.04 | 71.28 | 35.64 | 29.10 |
| PSI[DEG] | 100.0 | 110.0 | 120.0 | 130.0 | 135.0 | 140.0 | 145.0 | 150.0 | 155.0 |
| P[IN H2O] | 0.70 | 2.00 | 2.40 | 3.70 | 3.60 | 4.40 | 3.50 | 3.90 | 1.30 |
| V[FT/SEC] | 54.44 | 92.02 | 100.0 | 125.17 | 123.46 | 136.49 | 121.74 | 128.51 | 74.19 |
| PSI[DEG] | 160.0 | 165.0 | 170.0 | 175.0 | 180.0 | 185.0 | 195.0 | 205.0 | 215.0 |
| P[IN H2O] | 2.20 | 0.80 | 1.20 | 0.30 | 0.60 | 0.50 | 2.00 | 3.00 | 3.70 |
| V[FT/SEC] | 96.52 | 58.20 | 71.2 | 35.64 | 50.40 | 46.01 | 92.02 | 112.71 | 125.17 |
| PSI[DEG] | 225.0 | 250.0 | 260.0 | 270.0 | 280.0 | 290.0 | 300.0 | 310.0 | 315.0 |
| P[IN H2O] | 4.20 | 1.10 | 0.45 | 1.50 | 3.00 | 4.50 | 4.90 | 4.40 | 5.30 |
| V[FT/SEC] | 133.36 | 68.25 | 43.6 | 79.70 | 112.71 | 138.04 | 144.04 | 136.49 | 149.81 |
| PSI[DEG] | 320.0 | 325.0 | 330.0 | 335.0 | 340.0 | 345.0 | 350.0 | 355.0 | 360.0 |
| P[IN H2O] | 3.20 | 4.20 | 1.40 | 2.30 | 0.50 | 1.00 | 0.10 | 0.10 | 1.10 |
| V[FT/SEC] | 116.40 | 133.36 | 76.9 | 90.69 | 46.01 | 65.07 | 20.50 | 20.58 | 60.25 |

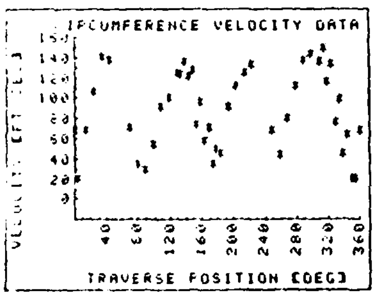



Table 15.

## LIST OF REFERENCES


1. Ellin, C. R., Model Test of Multiple Nozzle Exhaust Gas Eductor Systems for Gas Turbine Powered Ships, Engineer's Thesis, Naval Postgraduate School, June 1977.

2. Moss, C. M., Effects of Several Geometric Parameters on the Performance of a Multiple Nozzle Eductor System, Master's Thesis, Naval Postgraduate School, September 1977.

3. Lemke, R. J. and Staehli, C. P., Performance of Multiple Nozzle Eductor Systems with Several Geometric Configurations, Master's Thesis, Naval Postgraduate School, September 1978.

4. Shaw, R. S., Performance of a Multiple Nozzle Exhaust Gas Eductor System for Gas Turbine Powered Ships, Master's Thesis, Naval Postgraduate School, December 1980.

5. Ryan, D. L., Flow Characteristics of a Multiple Nozzle Exhaust Gas Eductor System, Master's Thesis, Naval Postgraduate School, March 1981.

6. Hill, J. A., Hot Flow Testing of Multiple Nozzle Exhaust Eductor Systems, Master's Thesis, Naval Postgraduate School, September 1979.

7. Harrell, J. P., Jr., Experimentally Determined Effects of Eductor Geometry on the Performance of Exhaust Gas Eductors for Gas Turbine Powered Ships, Engineer's Thesis, Naval Postgraduate School, September 1977.

8. Davis, C. C., Performance of Multiple, Angled Nozzles with Short Mixing Stack Eductor Systems, Master's Thesis, Naval Postgraduate School, September 1981.

9. American Society of Mechanical Engineers Interim Supplement 19.5 of Instrumentation and Apparatus, Fluid Meters, Sixth Edition, 1971.

10. Pucci, P. F., Simple Eductor Design Parameters, Ph.D. Thesis, Standord University, September 1954.

11. Kline, S. J. and McClintock, F. A., "Describing Uncertainties in Single-Sample Experiments," Mechanical Engineering, p. 3-8, January 1953.

## APPENDIX A: FORMULAE

Presented here are the formulas used to obtain the primary and secondary mass flow rates. According to the ASME primary Test Code [Ref. 9], the general equation for mass flow rate appearing in equation (a)

$$W(\text{lbm/sec}) = (0.12705)\ K\ A\ Y\ F_a\ (\rho\ \Delta P)^{0.5} \tag{a}$$

may be used with flow nozzles and square edge orifices provided the flow is subsonic. In the above equation, K (dimensionless) represents the flow coefficient for the metering device and is defined as $K = C(1 - \beta^4)^{-0.5}$ where C is the coefficient of discharge and $\beta$ is the ratio of throat to inlet diameters; $A(\text{in}^2)$ is the total cross sectional area of the metering device; Y (dimensionless) is the expansion factor for the flow; $F_a$ (dimensionless) is the area thermal expansion factor; $\rho$ ($\text{lbm/ft}^3$) is the flow mass density; and $\Delta P$ (inches $H_2O$) is the differential pressure across the metering device. Each of these quantities are evaluated, according to the guidelines set forth in Reference [8], for the specific type of flow measuring device used.

Using a square edge orifice for measurement of the primary mass flow rate, the quantities in equation (a) are defined as follows:

1. The flow coefficient K is 0.62 based on a $\beta$ of 0.502 and a constant coefficient of discharge over the range of flows considered of 0.60.
2. The orifice area is 37.4145 $in^2$.
3. Corresponding to the range of pressure ratios encountered across the orifice, the expansion factor Y is 0.98.
4. Since the temperature of the metered air is nearly ambient temperature, thermal expansion factor is essentially 1.0.
5. The primary air mass density $\rho_{or}$ is calculated using the perfect gas relationship with pressure and temperature evaluated upstream of the orifice.

Substituting these values into equation (a) yields

$$W_p \text{ (lbm/sec)} = (2.88455)\ (\rho_{or} \Delta P_{or})^{0.5} \qquad \text{(b)}$$

The secondary mass flow rate is measured using long radius flow nozzles for which case the quantities in equation (a) becomes:

1. For a flow nozzle installed in a plenum, $\beta$ is approximately zero in which case the flow coefficient is approximately equal to the coefficient of discharge. For the range of secondary flows encountered, the flow coefficient becomes 0.98.
2. A is the sum of the throat areas of the flow nozzles in use ($in^2$).

3. Since the pressure ratios across the flow nozzles are very close to unity, the expansion coefficient Y is 1.0.
4. Since the temperature of the metered air is nearly ambient temperature, the thermal expansion factor is essentially 1.0.
5. The secondary air mass density $\rho_s$ is evaluated using the perfect gas relationship at ambient conditions.

Substituting these values into equation (a) yields the equation for the secondary mass flow rate measured using long radius flow nozzles.

$$W_s \text{ (lbm/sec)} = (0.12451)\ A\ (\rho_s\ \Delta P_s)^{0.5} \qquad \text{(c)}$$

## APPENDIX B: UNCERTAINTY ANALYSIS

The determination of the uncertainties in the experimentally determined pressure coefficients, pumping coefficients, and velocity profiles was made using the methods described by Kline and McClintock [Ref. 11]. The basic uncertainty analysis for the cold flow eductor model test facility was conducted by Ellin [Ref. 1]. The uncertainties obtained by Ellin using the second order equation suggested by Kline and McClintock were applicable to the experimental work conducted during the present research and are listed in the following table.

UNCERTAINTY IN MEASURED VALUES

| | |
|---|---|
| $T_s$ | ± 1 R |
| $T_p$ | ± 1 R |
| $P_a$ | ± 0.01 psia |
| $\Delta P$ | ± 0.01 in. $H_2O$ |
| $P_V$ | ± 0.01 in. $H_2O$ |
| $P_u$ | ± 0.05 in. $H_2O$ |
| $\Delta P_s$ (+) | ± 0.01 in. $H_2O$ |
| $\Delta P_t$ (**) | ± 0.01 in. $H_2O$ |
| $P_{or}$ | ± 0.01 in. $H_2O$ |
| $\Delta P_{or}$ | ± 0.20 in. $H_2O$ |
| $T_{or}$ | ± 1 R |
| $T_a$ | ± 1 R |
| PT (***) | ± 0.1 in. $H_2O$ |

## UNCERTAINTY IN CALCULATED VALUES

| | |
|---|---|
| $\frac{P^*}{T^*}$ | 1.9% |
| $W^*T^{*0.44}$ | 1.4% |
| $V/V_{avg}$ | 2.5% |
| (+) | The pressure differential across the secondary flow nozzles, $P_s$. is the major source of uncertainty in the pumping coefficient. |
| (++) | The pressure differential across the tertiary flow nozzles, $P_t$, is the major source of uncertainty in the pumping coefficient. |
| (+++) | The measurement of the total pressure for the velocity profile is the major source of uncertainty in the velocity calculation. |

INITIAL DISTRIBUTION LIST

| | | No. of Copies |
|---|---|---|
| 1. | Defense Technical Information Center<br>Cameron Station<br>Alexandria, Virginia 22314 | 2 |
| 2. | Library, Code 0142<br>Naval Postgraduate School<br>Monterey, California 93940 | 2 |
| 3. | Department Chairman, Code 69<br>Department of Mechanical Engineering<br>Naval Postgraduate School<br>Monterey, California 93940 | 2 |
| 4. | Professor Paul F. Pucci, Code 69Pc<br>Department of Mechanical Engineering<br>Naval Postgraduate School<br>Monterey, California 93940 | 5 |
| 5. | Dean of Research, Code 012<br>Naval Postgraduate School<br>Monterey, California 93940 | 1 |
| 6. | Commander<br>Attn: NAVSEA Code 0331<br>Naval Ship Systems Command<br>Washington, DC 20362 | 1 |
| 7. | Mr. Olin M. Pearcy<br>NSRDC Code 2833<br>Naval Ship Research and Development Center<br>Annapolis, Maryland 21402 | 1 |
| 8. | Mr. Mark Goldberg<br>NSRDC Code 2833<br>Naval Ship Research and Development Center<br>Annapolis, Maryland 21402 | 1 |
| 9. | Mr. Eugene P. Wienert<br>Head, Combined Power and Gas Turbine Branch<br>Naval Ship Engineering Center<br>Philadelphia, Pennsylvania 19112 | 1 |
| 10. | Mr. Donald N. McCallum<br>NAVSEC Code 6136<br>Naval Ship Engineering Center<br>Washington, DC 21362 | 1 |

11. LT Carl J. Drucker, USN 1
1032 Marlborough Street
Philadelphia, Pennsylvania 19125

12. LCDR C. M. Moss, USN 1
625 Midway Road
Powder Springs, Georgia 30073

13. LCDR J. P. Harrell, Jr., USNR 1
1600 Stanley
Ardmore, Oklahoma 73401

14. LCDR J. A. Hill, USN 1
RFD 2, Box 116B
Elizabeth Lane
York, Maine 03909

15. LCDR R. J. Lemke, USN 1
2902 No. Cheyenne
Tacoma, Washington 98407

16. LCDR C. P. Staehli, USN 1
2808 39th St., N.W.
Gig Harbor, Washington 98335

17. LT R. S. Shaw, USN 1
147 Wampee Curve
Summerville, South Carolina 29483

18. LCDR D. L. Ryan, USN 1
6393 Caminito Luisito
San Diego, California 92111

19. LCDR C. C. Davis, USN 1
1608 Linden Drive
Florence, South Carolina 29501

20. LCDR D. Welch, USN 1
1036 Brestwick Commons
Virginia Beach, Virginia 23464

21. CDR P. D. Ross, Jr., USN 1
6050 Henderson Drive No. 8
La Mesa, California 92041

DATE

ILME